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# HERPETOFAUNA

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Common Spadefoot Toad *Neobatrachus sudelli* from Timmallallie National Park, NSW.  
See article on p. 71. (Photo: M. Murphy).

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# LARGER REPTILES RECORDED FROM WALKING TRACKS IN BRISBANE FOREST PARK, 1991 TO 2001: SEASONAL AND ANNUAL CHANGES AND HABITAT PREFERENCE

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## INTRODUCTION

Brisbane Forest Park is located to the west of Brisbane city on part of the D'Aguilar range (27°24'S 152°47'E). Timber reserves were first gazetted in the area in 1918 and Maiala National Park was declared in 1930 followed by Jolly's Lookout in 1938, Manorina in 1949 and Boombana in 1950. The Brisbane Forest Park Act 1977 established a new authority to provide collaborative management of national parks, state forests and council reserves for recreation and conservation. The park covers an area of over 28,000 ha and ranges in altitude from 43 to 770 m asl (Horton, 1988; [www.epa.qld.gov.au/parks\\_and\\_forests/](http://www.epa.qld.gov.au/parks_and_forests/)).

There have been several studies on the fauna and flora of Brisbane Forest Park but there is very little published on its reptiles apart from species lists which give a total of 20 snakes, 38 lizards and 4 chelonians (Plowman, 1985; Hines, 2002; Anon, undated).

In most fauna surveys, reptiles are sampled using methods such as pitfall and funnel traps (Hines & McDonald, 2007) but this technique does not sample the larger species which are generally just noted as incidental records. Very few surveys are repeated on a regular basis over a long time span, so precluding comparisons by season or year. In this report I present quantitative records of the larger reptiles recorded from systematic surveys on established walking tracks in Brisbane Forest Park over a 10-year period. In addition to documenting the presence of larger reptiles during the course of the survey, it also provides baseline data which will allow meaningful comparisons with possible changes in the future.

## STUDY AREA AND METHODS

This survey in Brisbane Forest Park was intended primarily to document bird populations but records of larger mammals and reptiles were also collected. Only birds in the stratum "ground level to 2m above ground" were recorded so observations were focused on the ground and just above it and not in the tree tops. Walked transects were conducted over a total of 12 km of existing tracks in Brisbane Forest Park and were undertaken twice a month from July 1991 to June 1994 ( $n = 73$ ) and then once or twice a month in summer (October to March) from 1994/5 to 2000/2001 ( $n = 52$ ). The route extended from Maiala to Alex Road via Greene's Falls and return to Maiala on the Western Track; a circuit at Mt Tennison-Woods; the Boombana circuit; and Boombana to Jolly's Lookout (see [http://www.epa.qld.gov.au/media/parks\\_and\\_forests/parks/bfp\\_track.pdf](http://www.epa.qld.gov.au/media/parks_and_forests/parks/bfp_track.pdf)). I endeavoured to walk as quietly as possible along the tracks to avoid disturbing animals before I encountered them. This would have been impossible on random transects through the vegetation without considerable and continued clearance of the vegetation. This would have been unacceptable in a national park.

This route included five habitat types (Table 1), based on the vegetation structural formations and map units of Young (1985).

No reptiles were captured and all identifications were made visually, sometimes with the aid of binoculars, with subsequent reference to guides such as Cogger (1979) and Covacevich (1970) for less familiar species. Reptiles were not the main focus of these transects so only large species were recorded and no attempt was made to record, follow or



**Table 1. Vegetation types traversed by walked surveys in Brisbane Forest Park. \* This excludes the first four kilometres of the transect (see text for details).**

Vegetation type	Equivalent vegetation formation in Young (1985)	Length of transect passing through this habitat (km)*
Notophyll closed forest (NCF)	F and G	2.943
Microphyll closed forest (MCF)	E	0.309
Riparian closed forest (RCF)	D	0.036
Wet sclerophyll open forest (WSOF)	C	1.810
Sclerophyll open forest (SOF)	B	2.910

search for smaller species. In the case of Land Mullet *Egernia major* and Major Skink *Egernia frerei*, individuals were often only glimpsed as they retreated into hollow logs or under cover and therefore the data for these two species should be treated with caution at the specific level although I am confident that they were large *Egernia* spp.

The distance of the transect was initially determined using a measuring wheel and the position of numerous landmarks (roads, tracks, stream crossings, etc) along the route was accurately recorded. During subsequent surveys, the location of each species observed along the transect was recorded using a pedometer, referenced back to these landmarks. This allowed allocation of each species record to a vegetation type.

I started about one hr after sunrise (mean of 0550 hr AEST in summer and 0720 hr AEST in winter) and finished 8 to 9 hours later. The first four kilometres of the transect yielded only 13 records of reptiles (8% of the total recorded) of six species (Table 2). This paucity of records is likely to be due to the early time of day (prior to ca 1030 hr) when few reptiles would be active. Therefore when determining densities and habitat preference (Tables 2-3), only the last eight kilometres of the transect have been used (150 records). All six species recorded in the first four kilometres of the transect were also recorded in the latter eight kilometres. Surveys were not undertaken if rain was forecast for the day.

Rainfall data (Figures 1-2) were obtained from the Bureau of Meteorology from the Mt Nebo Post Office meteorological station (487 m asl, mean annual rainfall 1349 mm) which was centrally located among the transects. This station did not record temperatures so those data were obtained from the more northerly Mt Glorious Fahey Rd station (618 m asl, mean annual rainfall 1612 mm).

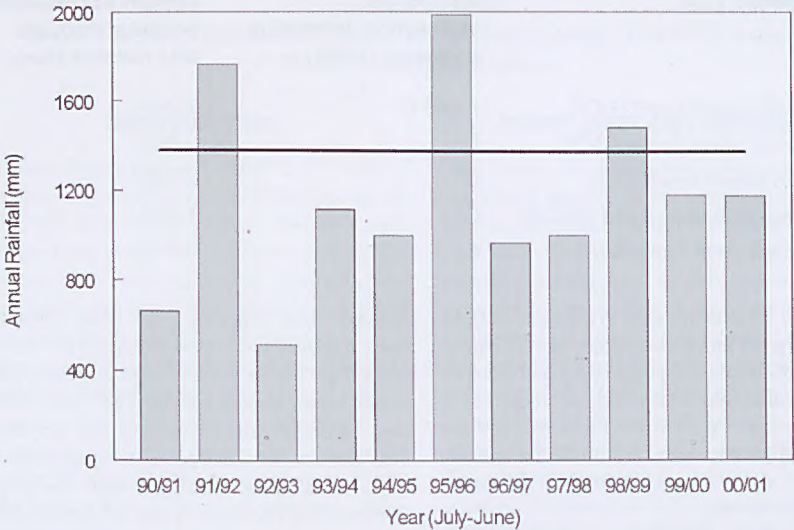
## RESULTS

### Species Recorded

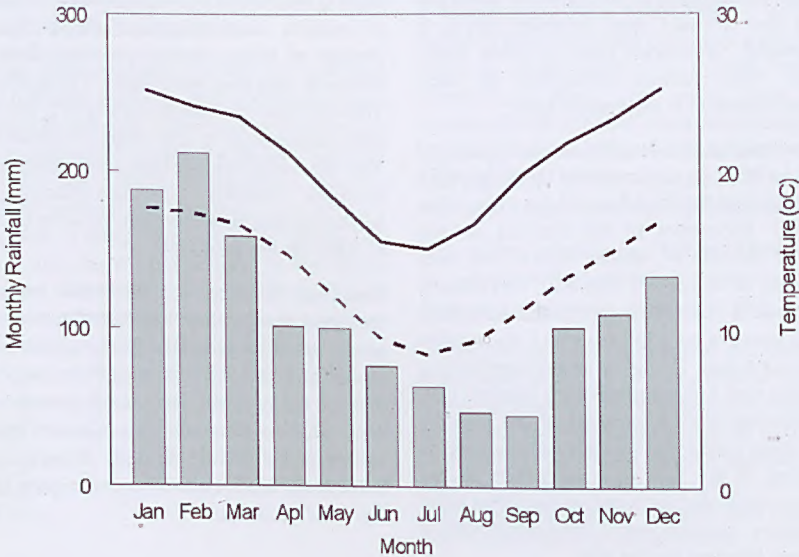
During the course of these surveys, 11 species of reptiles were identified (Table 2). The density of large reptiles recorded from the transects was low, with about 11 reptiles per 100 km over the whole survey (12 km transect), increasing to just over 19 reptiles per 100 km when the samples were restricted to summer months (October-March) and excluding the early morning, prior to ca 1030 hr AEST (8 km transect).

The Lace Monitor was the most frequently recorded species and represented over 42% of all reptile records. The "large skinks", Land Mullet and Major Skink, together contributed 37% of the records. Snakes represented only 19% of records with the Carpet Python, Yellow-faced Whip Snake, Rough-scaled Snake and Black-bellied Swamp Snake being the most recorded.

**Figure 1. Annual rainfall totals (mm), July to June 1990/1991 to 2000/2001 from the Mt Nebo meteorological station. The horizontal bar indicates the mean annual rainfall, 1947-2008.**



**Figure 2. Mean monthly rainfall totals (histograms) from Mt Nebo (1947-2008), and mean daily maximum (solid lines) and minimum temperatures (broken lines) from the Mt Glorious meteorological station (1933-2007).**

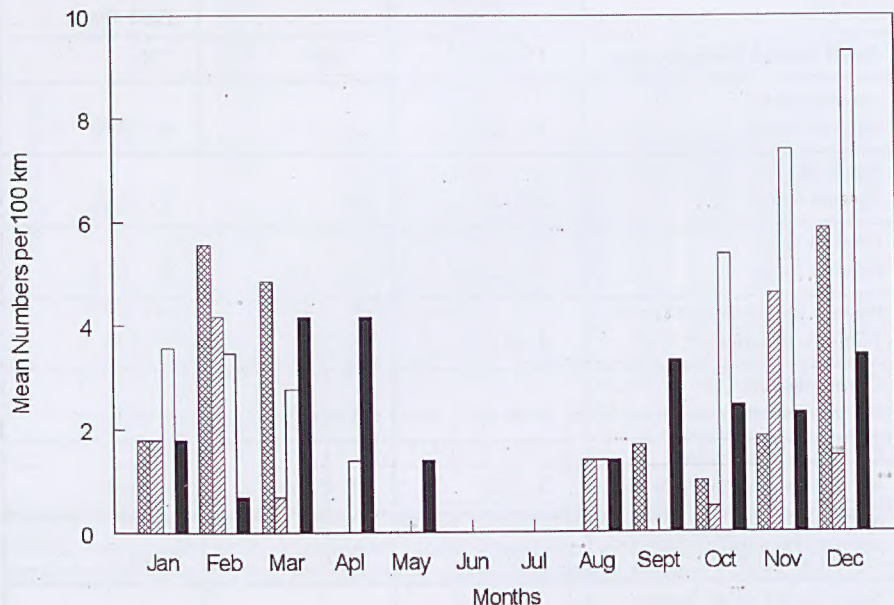




**Table 2. Large reptiles recorded from walked transects in Brisbane Forest Park, 1991 to 2000. Values are total numbers, with number per 100 km in parentheses.**

Species	From 125 x12 km transects	From 125 x 8 km transects	From 90 x 8 km transects in summer (Oct-Mar)
<b>Total survey length (km)</b>	1500	1000	720
Lace Monitor <i>Varanus varius</i>	63 (4.2)	62 (6.2)	60 (8.3)
Major Skink <i>Egernia frerei</i>	25 (1.7)	24 (2.4)	23 (3.2)
Land Mullet <i>Egernia major</i>	37 (2.5)	32 (3.2)	31 (4.3)
Eastern Blue-tongued Lizard <i>Tiliqua scincoides</i>	4 (0.3)	3 (0.3)	2 (0.3)
Carpet Python <i>Morelia spilota</i>	9 (0.6)	6 (0.6)	4 (0.6)
Common Tree Snake <i>Dendrelaphis punctulata</i>	3 (0.2)	3 (0.3)	3 (0.4)
White-crowned Snake <i>Cacophis harriettae</i>	1 (0.1)	1 (0.1)	1 (0.1)
Yellow-faced Whip Snake <i>Demansia psammophis</i>	7 (0.5)	7 (0.7)	5 (0.7)
Black-bellied Swamp Snake <i>Hemiaspis signata</i>	6 (0.4)	5 (0.5)	4 (0.6)
Eastern Small-eyed Snake <i>Cryptophis nigrescens</i>	1 (0.1)	1 (0.1)	0 (0.0)
Rough-scaled Snake <i>Tropidechis carinatus</i>	7 (0.5)	6 (0.6)	5 (0.7)
Total	163 (10.9)	150 (15.0)	138 (19.2)

**Figure 3. Seasonal changes in the mean number of reptiles recorded on 12 km walked transects in Brisbane Forest Park. Open bar = Lace Monitor, diagonal-shaded bar = Major Skink; cross-shaded bar = Land Mullet; solid bar = all snakes. (Sample sizes: Jan = 168 km; Feb-Mar = 144 km each; Apr-Aug = 72 km each; Sept = 60 km; Oct = 204 km; Nov = 216 km; Dec = 204 km; total = 1500 km).**



### Seasonal Changes

Seasonal changes of reptile numbers are presented in Figure 3. No large reptiles were recorded from these transects in June or July (144 km) and low numbers were recorded in May and August, then rising to a peak in November and December.

### Habitat Preferences

Table 3 shows the number of individual reptiles recorded in each of the vegetation types. The transect passed through a large distance of three vegetation types (NCF, WSOF, SOF) and the majority of reptile records (98%) were from these three types (Table 3) so analysis was restricted to these. Only three species

had sufficient records to allow an investigation of habitat preference. The Lace Monitor had relatively few records from NCF and more from WSOF and SOF. A chi-squared test showed a significant difference from the null hypothesis ( $H_0$ ) of no habitat preference (chi-squared = 9.1,  $df = 2$ ;  $p < 0.02$ ). Records of the Land Mullet showed no indication of a significant difference from the null hypothesis of no habitat preference (chi-squared = 3.01,  $df = 2$ ,  $p < 0.1$ ) but records of Major Skink showed a significant difference from the null hypothesis (chi-squared = 21.1,  $df = 2$ ,  $p < 0.001$ ), with relatively few records in NCF or WSOF but a larger number in SOF.



**Table 3. Large reptiles recorded from walked transects passing through five vegetation types in Brisbane Forest Park, 1999 to 2000. Values are total number of individual reptiles recorded per vegetation type (see Table 1), over 8 km transect, all months, n = 125 surveys. Values in parentheses are numbers/100 km.**

<b>Reptile Species</b>	<b>Total Numbers</b>				
<b>Vegetation Type</b>	NCF	WSOF	MCF	RF	SOF
Lace Monitor	12 (3.3)	16 (7.1)	1	1	32 (8.8)
Major Skink	2 (0.54)	2 (0.88)	0	0	20 (5.5)
Land Mullet	8 (2.2)	11 (4.9)	0	0	13 (3.6)
Eastern Blue-tongued Lizard	0	0	0	0	3
Carpet Python	2	0	0	0	4
Common Tree Snake	1	1	1	0	0
White-crowned Snake	1	0	0	0	0
Yellow-faced Whip Snake	0	0	0	0	7
Black-bellied Swamp Snake	1	0	0	0	4
Eastern Small-eyed Snake	0	0	0	0	1
Rough-scaled Snake	2	1	0	0	3
Total	29 (7.9)	31 (13.7)	2	1	87 (23.9)
Length of Transect in each Vegetation Type (m)	2943	1810	309	39	2910
Total survey length in each Vegetation Type (km)	368	226	39	5	364

## Annual Changes

Annual changes in the number of reptiles recorded from Brisbane Forest Park were investigated by dividing the records into three time periods (Table 4). Several species and numbers overall seemed to show declines over the ten years of survey and this was tested using a chi-squared test with a null hypothesis ( $H_0$ ) of no difference over the time periods. Only three species had sufficient records to allow this testing; Land Mullet showed a significant difference from the  $H_0$  (chi-squared = 18.6,  $df = 2$ ,  $P < 0.001$ ) but both Major Skink (chi-squared = 1.57,  $df = 2$ ,  $P < 0.3$ ) and Lace Monitor (chi-squared = 1.36,  $df = 2$ ,  $P < 0.5$ ) showed no significant differences. The numbers for all reptiles combined also showed a significant difference from the  $H_0$  (chi-squared = 11.2,  $df = 2$ ,  $P < 0.01$ ). If numbers for the two large *Egernia* skinks were combined, there was also a significant difference from the null hypothesis (chi-squared = 16.0,  $df = 2$ ,  $P < 0.001$ ).

## DISCUSSION

All the species recorded during these surveys are widespread in southeast Queensland (Covacevich, 1970; Wilson, 2005) and all have been previously recorded from Brisbane Forest Park (Anon, undated; Plowman, 1985). Apart from the White-crowned and Eastern Small-eyed Snakes, all were listed by Anon (undated) in the most common category "1. likely to be encountered in the preferred habitat on more than 50% of visits". The two exceptions were listed in the second category of probability of sighting "2. likely to be encountered in the preferred habitat on fewer than 50% of visits" and both of these were only recorded once on my surveys. The suggested probability of encounter of the "common" reptiles seems very optimistic because, even in summer months, after 1030 hr AEST, I encountered only one large reptile per five kilometres of transect (Table 2). I can find no comparable reports of reptile density in Australia.

**Table 4. Annual changes in the number of large reptiles (and numbers per 100 km) recorded from eight kilometre walked transects in Brisbane Forest Park, in summer (October – March).**

Years (July-June)	91/92 -93/94	94/95 -96/97	97/98 -00/01	Total
No. of surveys	38	30	22	90
Species				
Land Mullet	25 (8.2)	6 (2.5)	0 (0)	31 (4.3)
Major Skink	11 (3.6)	9 (3.8)	3 (1.7)	23 (3.2)
Eastern Blue-tongued Lizard	2 (0.7)	0 (0)	0 (0)	2 (0.3)
Lace Monitor	24 (7.9)	24 (10.0)	12 (6.8)	60 (8.3)
Carpet Python	2 (0.7)	2 (0.8)	0 (0)	4 (0.6)
Other snakes	6 (2.0)	10 (4.2)	2 (1.1)	18 (2.5)
All snakes	8 (2.6)	12 (5.0)	2 (1.1)	22 (3.1)
All reptiles	65 (23.0)	47 (21.3)	18 (9.7)	138 (19.2)



The absence of any reptile records in June and July (Figure 3) coincides with the coldest period of the year (Figure 2) and many other studies have shown that both lizards (de Lisle, 1996; King & Green, 1998; Klingenbock *et al.*, 2000; Guarino, 2002) and snakes (Shine, 1979; Slip & Shine, 1988; Shine & Fitzgerald, 1996; Torr, 2000) are inactive or have reduced activity during the winter months.

Varanids are inactive during the cold months in temperate regions (King & Green, 1998) and the Lace Monitor has been stated to be completely inactive from May to August (de Lisle, 1996). Guarino (2002) showed that Lace Monitors had the highest movement frequency and the greatest straight-line movement in summer and that agrees with the highest numbers encountered in this study during November and December.

The patterns of habitat preference recorded in this survey (Table 3) generally correspond with those reported in the literature. Lace Monitors were widespread and most often recorded in SOF with lower numbers in WSOF and NCF and this agrees with the habitat description of "well timbered" by Cogger (2000). Major Skinks were also most often recorded in SOF which corresponds with the "well-watered forested country or seasonally dry woodland" (Cogger, 2000). Land Mullet were recorded most often from WSOF, followed by SOF and NCF (Table 3). The relatively high numbers reported from SOF is at variance with the literature which reports their habitat as "rainforest and adjacent wet-sclerophyll forests" (Cogger, 2000; Wilson, 2005). Possible reasons for this are the misidentification of some Land Mullet for Major Skinks, as discussed above, and also the indistinct nature of some of the vegetation boundaries with the invasion of rainforest species into the adjacent WSOF and SOF. Kavanagh and Stanton (2005) found that Land Mullet favoured intensively logged sites in north-eastern New South Wales which had multi-layered foliage, a dense ground cover and fallen logs which is a more open habitat than the NCF in Brisbane Forest Park. The

other species of reptiles had too few records to allow meaningful comments on habitat preference but combining all species the preferred habitats were SOF, WSOF and NCF.

The numbers of Land Mullet, the two *Egernia* skinks combined and total reptiles showed significant declines over the 10 years of the survey. The reasons for this are not clear but rainfall and related productivity may be important. Annual rainfall totals were quite variable over the survey period (Figure 1) but only three years had above average annual rainfall. The mean rainfall for the three periods compared were all below the overall mean for Mt Nebo (Figure 1); the totals for 1991/92-1993/94, 1994/95-1996/97 and 1997/98-2000/01 were 82%, 96% and 88% respectively of mean rainfall and in 1992/93 the annual rainfall was only 38% of mean rainfall. It is possible that this deficit in rainfall reduced the productivity of prey items which in turn reduced the population sizes of the reptiles.

The Lace Monitor showed little change in numbers over the 10-year period. This species is well known for scavenging around picnic sites and this source of food may have allowed it to maintain its numbers. The recorded numbers for other species were too low to allow meaningful comparisons.

Long-term surveys of animal populations are essential to monitor their survival, particularly in relatively small protected areas. The returns for effort expended are meagre: after walking 1500 kms only three of eleven species have sufficient numbers to allow meaningful analysis and it is probably some of the rarer species that are most in need of monitoring. However, it is hoped that this study provides a baseline to measure future changes in the populations.

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# OBSERVATIONS OF FROG ACTIVITY IN AN AREA AFFECTED BY INTENSE WILDFIRE IN THE PILLIGA FOREST, NEW SOUTH WALES

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The response of amphibians to fire and associated habitat alteration is complex and currently poorly understood. Research and published observations in Australia (Bamford, 1992; Driscoll & Roberts, 1997; Lemckert, 2000; Lemckert *et al.*, 2003; Penman & Towerton, 2007) and North America (Gamradt & Kats, 1997; Schurbon & Fauth, 2003; Means *et al.*, 2004; Hossack & Corn, 2007) indicate that the effect of fire on amphibian communities can vary with fire intensity, fire frequency, time of year, time elapsed since fire, vegetation community and amphibian species. The effect of fire on amphibian populations can either be direct and immediate as a result of death of individuals from exposure to flames, smoke or intense heat, or indirect and longer-term through habitat alteration (Pilliod *et al.*, 2003). Direct effects will either be neutral (avoided) or negative, while changes to habitat suitability can range between negative and positive over time. This short paper briefly describes and discusses observations of frog activity at a site following a severe and extensive summer wildfire. Amphibian nomenclature follows Barker *et al.* (1995).

Timmallallie National Park is located in the central part of the Pilliga forest, in Gamilaraay Aboriginal Country in the Brigalow Belt South bioregion (Thackway & Creswell, 1995) of northern inland New South Wales. Timmallallie Dam (30°55'S 149°16'E) is a small earth-wall dam situated on a third order perennial stream in the Etoo sub-catchment of the Namoi River, in the central part of the park. The vegetation of the area is eucalypt-cypress pine dry woodland on Quaternary sands. A series of large wildfires in the eastern and central Pilliga forest in December 2006-January 2007 burned a total of about 160,000 ha. The area around Timmallallie Dam was burnt at a high to extreme intensity

with all ground vegetation and shrubs incinerated, tree trunks charred to 15 metres or higher and all canopy foliage scorched. The dam was dry at the time of the fire but filled following subsequent rain events. Post-fire regeneration of the vegetation from seed bank, lignotubers and epicormic growth has been slowly progressing since the fire.

Timmallallie Dam was visited about two hours after sunset on 1 September 2007 under mild, dry conditions following recent rain, and again about three hours after sunset on 24 September 2008 under mild, dry conditions several days after rain. One hour was spent searching for frogs on the first visit and 15 minutes on the second visit. Survey methods comprised looking for frogs with the aid of a 50 watt spotlight and listening for frog calls. The following frog activity was noted:

## **Northern Banjo Frog *Limnodynastes***

***terraereginae*:** approximately 25 frogs calling while floating amongst debris around the edge of the dam and in a pool below the dam wall in September 2007. Most of the frogs seen were closely associated with floating spawn masses, which were abundant around the margins of the dam. Several frogs were also active on the ground around the dam. Approximately five frogs calling from the edge of the dam and the pool below the dam wall in September 2008.

## **Common Spadefoot Toad *Neobatrachus***

***sudelli*:** one animal seen floating in the open in a pool in the creek line about 100 downstream of the dam wall and another three heard calling nearby in September 2007.

## **Broad-palmed Frog *Litoria latopalmata*:**

one animal seen active on the ground in the creek line about 100 downstream of the dam wall in September 2008.

**Figure 1. Northern Banjo Frog *Limnodynastes terraereginae* at Timmallallie Dam, Timmallallie National Park. Photo: M.J. Murphy.**



**Peron's Tree Frog *Litoria peronii*:** five frogs heard calling from elevated sites in trees close to the water's edge in September 2007.

Despite the bleak and apparently lifeless landscape in the immediate aftermath of the fire, several frog species had either been able to survive the wildfire event or recolonise the site in the period since the fire. The closest unburnt or lightly burnt area was at least three kilometres distant.

The ground frogs *Limnodynastes terraereginae* and *Neobatrachus sudelli* are both burrowing species, often remaining underground for extended periods and emerging only after rain (Cogger, 1992). Soil depths of as little as 5 cm can provide insulation from high temperatures during fires (Raison *et al.*, 1986; Bradstock & Auld, 1995) and frogs sheltering below the ground would be protected from the direct or immediate effects of wildfire. The tree frog *Litoria peronii* typically shelters under loose bark and in hollows of large

eucalypts (Barker *et al.*, 1995; Gibbons & Lindenmayer, 2002), and occasionally under rocks on the ground (Murphy, 1997). While any *L. peronii* sheltering under loose bark would probably have been killed by the intense fire, individuals in deep tree hollows or under rocks had a greater likelihood of survival. The ground-active hyliid *Litoria latopalmata* typically shelters by day beneath ground debris such as rocks and fallen timber (Murphy, pers. obs). As with the previous species, individuals sheltering under rocks may have survived the fire. Alternately (and noting the absence of detection in September 2007), this mobile species may have recolonised the site between September 2007 and September 2008.

The level of observation reported here (75 minutes over two nights) was not sufficient to determine whether the above four species were the only frogs surviving at Timmallallie Dam. The author had not visited the site prior to the 2006 fire. Records of frogs in the area



**Figure 2. Common Spadefoot Toad *Neobatrachus sudelli* at Timmallallie Dam, Timmallallie National Park. Photo: M.J. Murphy.**



(from the National Parks and Wildlife Service Atlas of NSW Wildlife database) prior to the 2006 fire include *Limnodynastes terraereginae*, *Litoria latopalmata* and *Litoria pèronii* at Timmallallie Dam and *Limnodynastes ornatus* and *Litoria rubella* within a 10 km radius of the site.

The central and eastern Pilliga forest is a fire-prone environment," with frequent wildfires

initiated by dry thunderstorms and large-scale wildfires occurring on average every 10 years. The observations recorded here indicate that at least some of the frogs species found in the Pilliga are apparently able to survive even high intensity wildfires and initiate breeding behaviour in fire-affected habitats.

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# PHYSICAL INTERACTION BETWEEN A MALE *NYCTIMYSTES DAYI* AND A SYMPATRIC MALE *LITORIA RHEOCOLA* (ANURA: HYLIDAE)

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## INTRODUCTION

A degree of separation between conspecific male anurans is often maintained by calling and physical contests. As males of different species do not compete for females, selection for interspecific aggression should be weak, and there are few reports of contest between heterospecific males (Gerhardt & Schwartz, 1995). If they do occur, interactions between heterospecific males appear to be as a response to trespassing or close calling proximity (see Table 1), similar to aggression between conspecifics (reviewed by Gerhardt & Schwartz, 1995).

## OBSERVATION

During routine nightly surveys of stream-dwelling anurans in Tully Gorge National Park (17 46'S 145 38'E, elevation 100 m),

frogs are captured and marked by toe-clipping to allow recognition of individuals at successive captures. On 18 October 2007 at 1915 hrs a male *Nyctimystes dayi* (#260, snout-urostyle length (SUL) 34.3 mm) was observed pinning a male *Litoria rheocola* (#341, SUL 31.9 mm). The encounter occurred on an emergent rock in the middle of a fast-flowing section of the stream. Events leading to the encounter are unknown as we only observed the pair struggling with each other between periods of remaining motionless. During periods of activity, the *L. rheocola* was observed trying to unsuccessfully escape, using its hind legs to try and dislodge the dominant *N. dayi* (see Figure 1). Separation only occurred when the frogs were captured. The *L. rheocola* was observed calling the following night on a rock 3 m downstream from the initial observation; the *N. dayi* has not been captured since.

**Table 1. Examples of inter-specific aggression in male anurans.**

Defensive Species	Intruder Species	Interaction Between Defender and Intruder	Aggressive Action by Defender	Reference
<i>Pseudophryne corroboree</i>	<i>Ranidella signifera</i> and <i>P. dendyi</i>	Trespassing intruder	Threat calls	Pengilly, 1971
<i>Colostethus inguinalis</i>	<i>C. pratti</i>	Trespassing intruder	Encounter calls and wrestling	Wells, 1980
<i>Hyla microcephala</i>	<i>H. ebraccata</i>	Close vocal or physical encounter	Aggressive calls and wrestling	Schwartz and Wells, 1985

## DISCUSSION

*Nyctimystes dayi* and *Litoria rheocola* are sympatric species on fast-flowing rainforest streams throughout their ranges, including Tully Gorge National Park. Male *N. dayi* usually call from rocks and vegetation within or adjacent to high velocity sections of rocky streams, while *L. rheocola* call from similar sites but at slower moving sections of the stream (Phillott, unpubl.). Both species appear to maintain inter-male spacing with a distance of approximately 1 m between conspecifics (Hodgkison & Hero, 2002) and male *N. dayi* have been observed in a similar posture with conspecifics prior to wrestling (Rowley, 2007). The encounter is most likely an example of aggression resulting as one frog encroached upon the perceived space of the other. It did not progress to wrestling whereby the frogs face each other and interlock forearms, as the interaction was interrupted by capture. Wrestling has been

observed among male *N. dayi* (Rowley, 2007) but not *L. rheocola*.

The *N. dayi* grasped the *L. rheocola* in an embrace similar to that during amplexus but it is less likely that the reported encounter is a misguided attempt at mating by the male *N. dayi*. Indiscriminate matings usually occur when there is an overlap between body sizes of conspecific and heterospecific females, the mating time is short, heterospecific females are rare, males are short-lived and conspecific females are large (Schmeller *et al.*, 2005). For *N. dayi*, only the latter is true; females are far larger than the males (SVL males: 32.7–41.9 mm, females 54.0–58.8 mm; McDonald & Alford, 1999). The breeding season for *N. dayi* is during the spring and summer (Barker *et al.*, 1995), *L. rheocola* females (28.4–41.2 mm; McDonald & Alford, 1999) are much smaller than *N. dayi*, and *N. dayi* males have been observed to breed over several seasons (Phillott, unpubl. data).

**Figure 1. A male *Nyctimystes dayi* pinning a male *Litoria rheocola* during a physical encounter.**





While it is unknown which individual initiated the encounter, the *N. dayi* was dominant at the time of observation. This could be due to greater aggression in this species or the size difference between the two individuals.

### ACKNOWLEDGMENTS

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**A CASE OF PREDATION BY AN ADULT  
RED-BELLIED BLACK SNAKE (*PSEUDECHIS PORPHYRIACUS*)  
ON AN ADULT EASTERN BROWN SNAKE (*PSEUDONAJA TEXTILIS*)**

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Predation by elapid snakes on other elapid snakes has been documented on numerous occasions (eg, Greer, 1997; Nicolson and Mirtschin, 1995). The Red-bellied Black Snake (*Pseudechis porphyriacus*) is one species known to feed on other snakes and has been recorded feeding on Blackish Blind Snakes (*Ramphotyphlops nigrescens*), Small-eyed Snakes (*Cryptophis nigrescens*), Black-headed Snakes (*Parasuta dwyeri*), Brown Tree Snakes (*Boiga irregularis*), Swamp Snakes (*Hemiaspis signata*) and other Red-bellied Black Snakes (Shine, 1977, 1987). This short note provides additional information on the diet of the Red-bellied Black Snake by documenting an observation of predation by an adult Red-bellied Black Snake on an adult Eastern Brown Snake (*Pseudonaja textilis*).

In Spring 2005, an adult Red-bellied Black Snake around 1.5 metres in length was observed moving rapidly across mown lawn

around a home near the farming community of Candelo (36°46'S 149°41'E), approximately 20 kilometres west of Bega, on the New South Wales far south coast. While the initial encounter between the two snakes was not observed, the Red-bellied Black Snake was observed 'spiralling' with an Eastern Brown Snake of approximately similar length. The observer left the scene quickly to retrieve a camera to photograph the event. On his return after an absence of less than three minutes, the Red-bellied Black Snake had begun to consume the Eastern Brown Snake, having hold of the animal by the head (Figure 1). Quickly, the Red-bellied Black Snake 'lined-up' the Eastern Brown Snake to begin swallowing (Figure 2). In less than ten minutes, almost all of the Eastern Brown Snake was consumed (Figure 3).

It is uncertain if the Eastern Brown Snake was actually alive at the time of the confrontation.

**Figure 1. Less than three minutes after the 'spiralling', the Red-bellied Black Snake had begun to consume the similarly-sized Eastern Brown Snake having hold of the animal by the head (Photo: John Coman).**





**Figure 2. The Eastern Brown Snake was 'lined-up' quickly for swallowing (Photo: John Coman).**



**Figure 3. Less than ten minutes from the initial attack, the Eastern Brown Snake has been all but consumed with only a small section of its tail remaining visible (Photo: John Coman).**



However, the observer felt that both snakes were alive during the spiralling, with certainty that movement was observed in the Eastern Brown Snake. By the time the observer had returned with the camera, no movement was visible by the Eastern Brown Snake with the Red-bellied Black Snake having a hold on its head (Figure 1).

The rapid movement of the Red-bellied Black Snake across the lawn area suggests that the Eastern Brown Snake may have been the target of a calculated attack. This observation supports existing evidence of *Pseudechis* pre-dating on other snakes further suggesting that this behaviour could be a specific trait amongst this genus that is infrequently observed.

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**A RECORD OF OPHIOPHAGY BY THE SPOTTED PYTHON  
*ANTARESIA MACULOSA* (SERPENTES: PYTHONIDAE) FROM  
MURRAY FALLS NATIONAL PARK, NORTH QUEENSLAND, AUSTRALIA**

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## INTRODUCTION

Many snakes are known to include other snakes in their diet (Greene, 1997) but only one Australian snake, the Bandy Bandy (*Vermicella annulata*), an elapid, can be regarded as a specialist predator on other snakes, feeding primarily on blindsnakes (Shine, 1980). Other Australian elapids, mainly *Austrelaps* (Shine, 1987a; Fearn, 1994, 1995), *Pseudechis* (Shine, 1977, 1987b) and *Pseudonaja* (Shine, 1989; Neindorf, 1994) also prey on snakes as part of their diet (see also Greer, 1997). By comparison, pythons do not appear to regularly prey upon snakes. Within the Australo-Papuan python radiation, observations of ophiophagy have been reported from *Antaresia childreni* (Kend, 1997), *Apodora papuana* (O'Shea, 1988; Mavromichalis & Bloem, 1994), *Aspidites melanocephalus* (Fleay, 1941; Kend, 1997), *A. ramsayi* (Shine & Slip, 1990), *Bothrochilus boa* (Bell, pers. obs.), *Liasis fuscus* (Shine, 1991; Anon, 2007; Huddleston, pers. obs.), *Liasis olivaceus* (Shine & Slip, 1990; Kend, 1997; O'Shea, 2007) and *Morelia viridis* (Jago, 1994). Here I report an observation of ophiophagy by the Spotted Python *Antaresia maculosa*.

## OBSERVATION

On 23 April 2005 at around 1400 hours I observed an adult male *Antaresia maculosa* (1154 mm snout-vent length, total length 1259 mm, weight 530 g; Figure 1) near a barbecue area at Murray Falls National Park, south of Tully, North Queensland (18°09'08"S 145°48'53"E). As the barbecue area was occupied by several people I decided to catch

the snake and relocate it away from this area for its safety. Upon capture the snake disgorged a recently-ingested adult female keel-back snake, *Tropidonophis mairii* (761 mm snout vent length, total length 891 mm, weight 170 g). The snake was released immediately after and the *Tropidonophis* was dissected to determine its sex and reproductive status and found to contain two recently ingested *Bufo marinus* (approx. 30 mm SVL).

## DISCUSSION

Although a specimen of *Antaresia childreni* was observed "to pursue, subdue, and eat a non-venomous *T. mairii*" (Kend, 1997) there appear to be no other published records of ophiophagy in this genus. Comprehensive dietary studies on museum specimens of *Antaresia* species by Slip and Shine (1990) showed a diet of frogs, mammals, and lizards with no snakes noted. Similarly, my examination of numerous *A. maculosa* from around the Townsville, North Queensland area has not recorded snakes in the diet.

Pythons are known to consume large heavy prey but, with the possible exception of *Aspidites melanocephalus*, are not often associated with elongate prey, despite other families of snakes preying on such items (Greene, 1983). Recent research into ophiophagy by the California Kingsnake *Lampropeltis getula californica* found that in order for snakes to consume other snakes the predator's stomach had to be stretched longitudinally to accommodate the prey (Jackson *et al.*, 2004). They conducted five trials in which a live Corn Snake *Elaphe guttata* was fed to *L. getula californica* with only one trial ending with full

**Figure 1. Spotted python (*Antaresia maculosa*) from Murray Falls National Park, Queensland, that had swallowed a Keelback (*Tropidonophis mairii*).**



digestion of the prey. These results give the impression that even snakes known to practice opithophagy may not be morphologically adapted to eat snakes and that these snakes can have difficulty in fully digesting their prey.

*Antaresia* species have a catholic diet (Shine, 1990) and are also known to consume road-killed skinks (Switak, 1989) and agamids (Trembath *et al.*, 2007). This broad scale diet along with an acceptance to prey on dead items may allow them to take advantage of the relative abundances of prey including high densities of snakes they come in contact with.

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# THE DISTRIBUTION AND CONSERVATION STATUS OF BARRED FROGS IN THE SYDNEY BASIN PART 2. STUTTERING FROG *MIXOPHYES BALBUS*

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## ABSTRACT

Intensive surveys for the Stuttering Frog *Mixophyes balbus* in the Sydney Basin were carried out between 1999 and 2007 to assess its current range and to assess the extent of recent declines. One hundred and forty-four sites were searched covering the recorded historic sites as well as sites identified with suitable habitat. We located *M. balbus* at 18 locations; six of which were historic sites. Extant populations occurred at mean elevation 238 m ASL; this altitude is substantially less than the mean elevation of 364 m for all known historic sites. Extant populations are mostly confined to first or second order streams in closed forest gullies, and contrary to expectations, 11 out of the 18 populations occur in areas disturbed by forestry activities. This species has declined significantly in the region and is of great conservation concern.

## INTRODUCTION

Barred Frogs (genus *Mixophyes*: Family Myobatrachidae) are represented by four species in New South Wales, three of which have undergone substantial losses in range and abundance since the 1970s (Parris, 2002). Three species, the Stuttering Frog *M. balbus*, the Giant Barred Frog *M. iteratus* and the Great Barred Frog *M. fasciolatus*, occurred in the Sydney Basin south of the Hunter River and west in the Blue Mountains National Park. The decline of these three species has reportedly been most severe in the southern part of their range, particularly south of Newcastle (Mahony *et al.*, 1997a, b).

The current distribution of *M. iteratus* is presented in Part 1 (White, 2008) of this series of papers. The present paper assesses the current distribution of *M. balbus* in this area.

*Mixophyes balbus* (Figure 1) had a distribution that extended from the New England District of New South Wales south into north-eastern Victoria; a comprehensive survey for this species south of Sydney located only two extant populations (Daly *et al.*, 2002). The status of populations in the ranges from the Illawarra escarpment north to the Hunter River has also declined (Mahony *et al.*, 1997b). The decline in range and abundance of this species has resulted in the Stuttering Frog being listed as "endangered" in both New South Wales (Threatened Species Conservation Act 1995) and Victoria (Flora and Fauna Guarantee Act 1988). *Mixophyes fasciolatus* is the only species of *Mixophyes* in New South Wales that is not listed as a threatened species but its distribution and status will be assessed in the third and final paper in this series.

Many of the historic locations for *M. balbus* in the Sydney Basin were located in national parks or in conservation areas (such as state forests). The Blue Mountains region to the west of Sydney, for example, contains several large national parks (such as Wollemi, Blue Mountains and Kanangra-Boyd National Parks), water catchment areas, reserves and state forests. To the north of Sydney, *M. balbus* was historically recorded from sites in the Wollemi NP and state forests and reserves in the Watagan Mountains. These areas rep-

resent highly protected and actively conserved lands where native fauna is relatively unaffected by human activity but declines have occurred in these areas as well as less protected sites (Gillespie & Hines, 1999).

In this study, which extended over six years, all historic locations (pre-1970) for *M. balbus* were surveyed. In addition, areas of potentially suitable habitat were sought, identified and surveyed. Reports of possible sightings of the frogs were also investigated. Habitat variables of sites where *M. balbus* currently occurs were compared with habitats from historic (but no longer occupied) sites. These surveys complement similar surveys carried out for *M. balbus* in southern New South Wales (Daly *et al.*, 2002).

## METHODS

### Survey Area

The survey area was confined to the northern part of Sydney Basin and nearby areas in central, eastern New South Wales. This comprised an area extending as far as Bathurst to the west, the Hunter River to the north and Macquarie Pass to the south. Survey sites ranged in elevation from 30 m above sea level (ASL) at Gosford to 910 m at Mount Wilson (Zircon Creek).

Survey sites included a range of habitats including tall-closed forest, closed forest, low-closed forest, tall forest, forest and open forest (Specht, 1981).

### Site Selection

Historic sites (pre-1970) were compiled from various sources including the National Parks and Wildlife Services' (NPWS) Wildlife Atlas, the Australian Museum, the Museum of Victoria and records from amateur herpetologists. All historic sites (Table 1) were visited and surveyed as part of this study.

Sites with potentially suitable habitat were also surveyed. Habitat modelling was carried out by NPWS to better target prospective survey areas. A computer-based modelling

package was used to examine relationships between the location of species sightings and environmental attributes such as climate, terrain, vegetation type and geology. Once significant associations were found between the sighting records and habitat variables, predictions were then made over the rest of the survey area to locate apparently suitable habitat areas where the species had not previously been recorded. Wherever access to potential habitat areas was possible, the sites were visited and assessed first-hand to see if they matched the predicted habitat characteristics. If habitat appeared to be present, the site was surveyed. Some areas could not be surveyed as potential habitat areas were too distant from road or helicopter landing sites. An effort was made to survey at least one location in each catchment system predicted to contain suitable habitat.

Since 2004, NPWS initiated a Sydney-wide survey of all terrestrial vertebrates. Refinements to the habitat modelling program identified additional prospective areas for targeted surveys. Survey teams of between six to eight people surveyed each area for between four and ten days at a time. Where potentially suitable habitat for *M. balbus* was identified, the survey team used call playback and tadpole surveys to supplement nocturnal streamside searches.

### Survey Dates and Locations

The main targeted survey effort for *M. balbus* was concentrated between November 1999 and April 2000. Follow-up surveys were carried out each year in the spring and summer period in response to claimed sightings of the frog species in the survey area.

The spring-summer of 1999-2000 was an above-average rainfall period where rain fell regularly over the five months of the survey. Site surveys were carried out in geographic area units to maximise the number of sites that could be covered during a wet period. Each survey period usually extended for between four and six days; the survey dates and times for this period are presented in



Table 1 in White (2008). One hundred and nine sites were surveyed during the 1999–2000 period while another five sites were surveyed (often more than once) over the next three years.

The general terrestrial fauna surveys carried out by NPWS since 2004 targeted the public lands in the northern parts of the Sydney basin including northern Wollemi NP, south-eastern Wollemi NP, Yengo NP, Parr State Conservation Area, Manobalai Nature Reserve and Werakata National Park. The most recent (December 2007) surveys were in north-eastern Blue Mountains NP.

### Pre-survey Assessment of Sites

The exact location of many historic and potential survey sites needed to be determined before night surveys could commence. The vicinity of each site was traversed on foot during daylight hours until the location had been determined. While it was light it was also possible to determine the best means of access to riparian areas, visit landowners (if private property needed to be crossed) and search for tadpoles. The vegetation and topographic features of each site were recorded and transferred to data sheets for incorporation into future habitat modelling. In addition, an assessment of any apparent threats at each site was made, based on visual observations of each site.

### Survey Methods

Searches for adult *Mixophyes* were carried out at night under favourable weather conditions i.e. warm nights following rain. Surveys included spotlighting for non-calling frogs, stream transects and play-back calling. Initially, playback recordings were broadcast from a small, portable amplifier but this proved to be inefficient. Instead, playback recordings were played from a hand-held cassette recorder that was played repeatedly throughout the survey. The cassette recorder had a much lower volume than the amplifier but was more useful as it did not "drown out" the response calls of frogs.

Frog transects were carried out on foot. Where possible, 200 m of stream bank was traversed on foot, with call playback being made at 25 m intervals with listening stops midway between playback sites.

During the day, tadpole surveys were carried out. Tadpoles were netted using a long-handled dip net. They were transferred to a plastic bag for identification, and returned to the site of capture once the identity was determined (tadpole identification was based on Anstis, 2002). If the tadpole was small and may have been *Mixophyes*, it was retained and transported back to Sydney where it was housed and reared to a point where its identity could be confirmed. NPWS terrestrial vertebrate surveys include targeted frog surveys; these consisted of systematic nocturnal streamside search (30 minutes per site), systematic spotlighting (30 minutes per site), and opportunistic daytime searches for tadpoles and call playback for *M. balbus* (five minutes of playback and ten minutes of listening) in some locations.

The survey also looked for sick or dead frogs. These were to be collected (as per NPWS protocol; NPWS, 2001). If adult *Mixophyes* were located they were not handled unless their identity was uncertain. Care was taken to ensure that disease transfer minimisation techniques were used. Frogs were not bagged and not brought in contact with other frogs. After handling frogs, hands were washed and rinsed in a weak solution of Benzalconium. During tadpole surveys, tadpoles that were netted were transferred to a sterile plastic bag (which was not re-used), identified and immediately released.

## RESULTS

### Historic Sites

Forty historic sites were visited and surveyed. These sites ranged from the Watagan National Park in the north to Wombeyan Caves in the south-west (Table 1).

**Table 1. Historic Sites for *Mixophyes balbus*.**

Location	Source	Year	Latitude & Longitude	Altitude (m asl)	Habitat
Kurrajong Heights	Aust. Museum	Unknown	33°29'S 150°35'E	350	Tall Forest
Illawarra Escarpment	Aust. Museum	Unknown	34°23'S 150°49'E	150	Closed Forest
Burrawang	Aust. Museum	Unknown	34°38'S 150°30'E	110	Closed Forest
Mt Wilson	Aust. Museum	Unknown	33°30'S 150°22'E	890	Closed Forest
Moss Vale	Aust. Museum	Unknown	34°34'S 150°22'E	440	Closed Forest
Blackheath	Aust. Museum	Unknown	33°38'S 151°16'E	800	Closed Forest
Wombeyan Caves	Aust. Museum	Unknown	34°20'S 149°58'E	650	Forest
Mount Irvine	Aust. Museum	Unknown	33°29'S 150°29'E	550	Closed Forest
Linden	Aust. Museum	Unknown	33°44'S 150°30'E	400	Tall Forest
Royal National Park	Aust. Museum	1954, 1962-1963	34°10'S 151°01'E	60	Closed Forest
Robertson	Aust. Museum	1963	34°33'S 150°36'E	580	Closed Forest
Faulconbridge	Aust. Museum	1964-1965	33°43'S 150°32'E	320	Tall Forest
Newnes Glow-worm Tunnel	Aust. Museum	1965	33°15'S 150°09'E	440	Forest
Mt Kiera	Aust. Museum	Unknown, 1965	34°23'S 150°48'E	140	Closed Forest
Stanwell Park	Aust. Museum	1970	34°14'S 150°59'E	60	Tall Closed Forest
Darkes Forest	Aust. Museum	1972	34°14'S 150°55'E	310	Tall Forest
Ridgeway, Gosford	Aust. Museum	1972	33°23'S 151°25'E	30	Tall Closed Forest
Newnes Plateau	Aust. Museum	1972	33°25'S 150°12'E	700	Forest
Morrisett	Aust. Museum, M. Anstis	1973	33°07'S 151°28'E	110	Closed Forest
Jenolan Caves	Aust. Museum	1974	33°50'S 150°01'E	400	Forest

Location	Source	Year	Latitude & Longitude	Altitude (m asl)	Habitat
Macquarie Falls	Aust. Museum	1976	34°35'S 150°38'E	300	Closed Forest
Watagan SF	Aust. Museum	Unknown, 1977	33°01'S	120	Closed Forest
Boarding House Dam	Aust. Museum	1976, 1977	33°00'S 151°25'E	300	Closed Forest
Bundanoon	Aust. Museum	1977	34°40'S 150°20'E	530	Closed Forest
Cut Rock Ck, Olney SF	M. Mahony	1978	33°03'S 151°25'E	70	Closed Forest
Canada Drop Down Ck, Olney SF	M. Mahony	1978	33°20'S 151°20'E	60	Closed Forest
Felled Timber Ck, Olney SF	M. Mahony	1978	33°02'S 151°26'E	150	Closed Forest
creek, Pines Camping Area, Olney	M. Mahony	1978	33°04'S 151°20'E	190	Closed Forest
trib. of Watagan Ck, Olney SF	M. Mahony	1979	33°01'S 151°20'E	300	Closed Forest
St Albans	M. Mahony	1979	33°12'S 150°55'E	180	Tall Forest
Strickland SF	Wildlife Atlas	1992	33°23'S 150°20'E	60	Tall Closed Forest
Muir's Lookout, Olney SF	Wildlife Atlas	1996	33°06'S 151°21'E	210	Tall Closed Forest
Burnt Bridge Ck, Olney SF	Wildlife Atlas	1997	33°05'S 151°24'E	120	Closed Forest
Helensburg	J. Rice	1997	34°11'S 151°00'E	60	Closed Forest
Ourimbah SF	Wildlife Atlas	1998	33°33'S 151°20'E	40	Closed Forest
Awaba SF	SFNSW	1999	33°18'S 151°28'E	60	Closed Forest
Sawpit Gully, Olney SF	SFNSW	1999	33°07'S 151°24'E	40	Closed Forest
Breaches Gully, Olney SF	SFNSW	1999	33°07'S 151°24'E	70	Closed Forest
Jilliby Jilliby Ck, Olney SF	SFNSW	1999	33°12'S 151°22'E	110	Closed Forest
trib. of Wyong R., Olney SF	SFNSW	2000	33°19'S 151°20'E	100	Closed Forest



### ***Mixophyes balbus* sites found during 1999-2007.**

Between 1999-2007 eighteen extant populations of *M. balbus* were found (Table 2, Figure 2).

Many of these populations were found during this survey but others were found by State Forests of New South Wales (SFNSW) or by other researchers in the field.

**Table 2. *Mixophyes balbus* sites found during 1999-2007.**

Location	Source	Year	Latitude & Longitude	Altitude (m asl)	Habitat
Cut Rock Ck, Olney SF	M. Mahony	1999	33°03'S 151°25'E	70	Closed Forest
Canada Drop Down Ck, Olney SF	M. Mahony	1999	33°20'S 151°20'E	60	Closed Forest
Felled Timber Ck, Olney SF	This survey	1999	33°02'S 151°26'E	150	Closed Forest
Strickland SF	R. Wellington	1999	33°23'S 150°20'E	60	Tall Closed Forest
trib. of Little Jilliby Ck, Olney SF	This survey	1999	33°12'S 151°20'E	100	Closed Forest
Burnt Bridge Ck, Olney SF	This survey	1999	33°05'S 151°24'E	120	Closed Forest
trib. of Gap Ck, Olney SF	This survey	1999	33°01'S 151°25'E	80	Closed Forest
trib. of Jilliby Jilliby Ck, Olney SF	SFNSW	1999	33°13'S 151°20'E	50	Closed Forest
Awaba SF	SFNSW, This survey	1999, 2000	33°18'S 151°28'E	60	Closed Forest
Sawpit Gully, Olney SF	SFNSW	1999, 2000	33°07'S 151°24'E	40	Closed Forest
Breaches Gully, Olney SF	SFNSW	1999	33°07'S 151°24'E	70	Closed Forest
Jilliby Jilliby Ck, Olney SF	SFNSW	1999	33°12'S 151°22'E	110	Closed Forest
Macquarie Pass	This survey	2000	34°35'S 150°38'E	300	Closed Forest
trib. of Wyong R., Olney SF	SFNSW	2000	33°19'S 151°20'E	100	Closed Forest
Mt Werong East	This survey	2004	34°05'S 149°57'E	900	Forest
Mt Werong West	This survey	2004	34°05'S 149°52'E	980	Forest
Trib. of Wollemi Creek	NPWS	2006	32°50'S 150°30'E	580	Closed Forest
Widden Brook	NPWS	2007	32°45'S 150°15'E	400	Closed Forest

**Figure 1. Adult Stuttering Frog *Mixophyes balbus*, Cut Rock Creek, March 2000 (photo: A. White).**



Of the 18 current sites, five were associated with first order streams, seven with second order streams, four with third order streams and one with a fourth order stream.

#### **Nature of Habitat for *M. balbus***

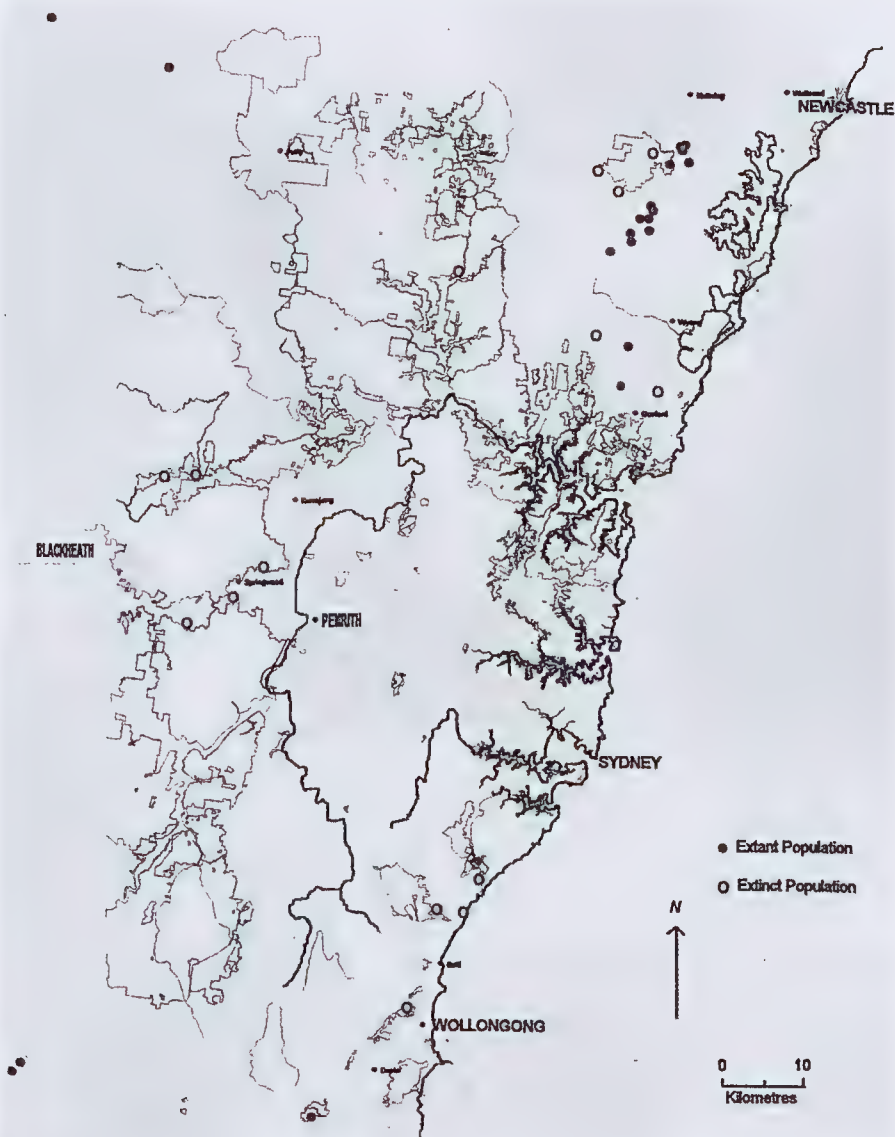
In general, the riparian habitat associated with *M. balbus* sites seemed to fall into five vegetation associations: tall closed forest (TCF), tall forest (TF), closed forest (CF), forest (F) and low-closed forest (Specht, 1981). These communities were often dominated by "typical" tree species. For example, tall closed forest often contained large stands of Blue Gums (*Eucalyptus deanei*, *E. saligna*) and Water Gums (*Tristaniopsis laurina*) with an understorey of Bangalow Palms and lianas; tall forest often contained coachwoods (*Cer-*

*atopetalum apetalum*), sassafras, black wattle (*Callicoma serratifolia*) and tree ferns; closed forest contained turpentines (*Syncarpia*), Blue Gums (*E. saligna*/*E. deanei*) and had a dense ground cover while forest was dominated by a variety of smaller-leaved eucalypts (forest gums, ironbarks, stringybarks, mahoganies) and she-oaks (*Casuarina*) with relatively sparse ground cover.

While these plant assemblages are not mutually exclusive and some catchments had more than one habitat type along them, the dominant habitat type was recorded for each site. The historic sites were then grouped according to main habitat type present.

Twenty seven (68%) of the sites were in located in closed forest; four (10%) were

Figure 2. Map showing locations of extant and extinct sites for *Mixophyes balbus*.





located in tall-closed forest (Stanwell Park, Ridgeway, Gosford, Muirs Lookout Olney SF, Strickland SF), six (15%) were in tall forest (Kurrajong Heights, Linden, Faulconbridge, Darkes Forest, Newnes Glow Worm Tunnel, St Albans), while the remaining three (8%) were in tall forest or forest (Newnes Plateau, Jenolan Caves, Wombeyan Caves).

A similar analysis of habitat of extant sites was carried out. Only three habitat types currently contain *M. balbus*, with 15 of the 18 extant sites (83%) in closed forest, one (Strickland SF) in tall-closed forest while two (Mt Werong East, Mt Werong West) were in forest.

### **Altitude of *M. balbus* Sites**

The average elevation recorded was 364 m asl with a range between 40 and 890 m asl. The average elevation of extant *M. balbus* sites was 238 m asl with a range between 40 and 980 m asl. Of the 18 extant sites, only four (Mt Werong East, Mt Werong West, Wollemi Creek and Widden Brook) were above 120 m asl.

### **Distance from the Coast of *M. balbus* Sites**

Historic *M. balbus* sites were scored according to whether they were within 50 kilometres of the coast. Thirty out of 40 (75%) sites were within 50 kilometres of the coast. Of the 18 extant populations found, 14 (78%) were within 50 kilometres of the coast; the four high elevation sites (Mt Werong East, Mt Werong West, Wollemi Creek and Widden Brook) were further inland from the coast.

### **Number of *M. balbus* Populations South of Sydney**

Of the 40 historic locations for *M. balbus* 12 (29%) were south of Sydney.

Of the 18 extant populations of *M. balbus* three (17%) were south of Sydney.

### **Breeding Sites for *M. balbus***

Although calling was heard at many of the extant sites, tadpoles of *M. balbus* were only found in eight sites (Burnt Bridge Creek,

Canada Drop Down Creek, Cut Rock Creek, Gap Creek, Felled Timber Creek, Mt Werong East, Mt Werong West and Widden Brook).

## **DISCUSSION**

### **Changes in the Distribution of *M. balbus***

The results of this study (Figure 2) demonstrate that *Mixophyes balbus* has undergone a loss of populations and a reduction in range. Of the 18 extant populations found, only three were south of Sydney (Macquarie Pass, Mt Werong East and Mt Werong West). The remaining 15 populations were concentrated in the Watagan Mountain block, north of Sydney.

*Mixophyes balbus* has undergone a massive reduction in geographic range and has been virtually eliminated from most of the southern half of its historic range. In southern New South Wales, Daly *et al.* (2002) were only able to locate two extant populations (from over 100 sites surveyed) in the area between Macquarie Pass and the Victorian border. *Mixophyes balbus* was only ever known from three sites in Victoria and has not been found in Victoria for over twenty years: it may be extinct in that state (Gillespie & Hines, 1999).

In addition to the loss of sites in the Sydney Basin, only two extant sites were found that were more than 50 kilometres inland of the coast (Mt Werong East and Mt Werong West). The combined effect of the southern and western losses of populations has been to confine *M. balbus* to the north-eastern portion of its former range in the Sydney Basin. This restriction of range means that the Macquarie Pass and Mt Werong (East and West) Stuttering Frogs have become isolated outliers and are more than 50 kilometres from their nearest neighbouring populations.

There has also been an apparent change in habitat utilisation by *M. balbus*. In particular, drier (non-rainforest) habitats such as tall forest and forests rarely contained extant populations of Stuttering Frogs. Closed forest has become increasingly the dominant vege-

tation type that is occupied. This vegetation association is present in many sheltered gullies and valleys along the eastern Divide, such as in the Blue Mountains, Wollemi and Illawarra but *M. balbus* is no longer present in these areas. In north-eastern New South Wales, statistical modeling was used to predict environmental regimes of Stuttering Frogs (NPWS, 1994); this study found that the frogs were strongly correlated with large forest tracts in areas of relatively cool mean annual temperatures; these habitats are more extensive along the southern parts of the Great Divide than in northern New South Wales.

One factor that appears to have had an overriding effect on the change of distribution of *M. balbus* in the northern Sydney Basin is altitude. Historic populations occurred at elevations between 40 and 890 m asl (with a mean of 364 m asl). This has altered somewhat with most high elevation sites being no longer occupied. Mean elevations for extant habitats are 238m asl, less than the mean for historic sites despite the addition of the two highest sites (Mt Werong East and West) so far found. This pattern of altitudinal loss of sites is consistent with the "global decline" phenomenon reported for many frog species (Gillespie & Hines, 1999).

### **Status of *M. balbus* in the Sydney Basin Region**

In view of the extensive reduction in distribution of the species and in particular, its virtual disappearance from habitat areas of high elevations, *M. balbus* must be regarded as an endangered species in the Sydney Basin region. In the Watagan Mountain block, where the species is most abundant, *M. balbus* is present in almost all eastern-flowing drainages and their tributaries. The headwaters of these drainage systems are almost completely confined to state forests or national parks. Hence, the habitats used by these frogs in this area are relatively secure.

*Mixophyes balbus* has declined to such as extent in the Blue Mountains that it is facing

regional extinction in this area. Two populations of *M. balbus* were found in predicted habitat areas in the Wollemi NP but the frogs were not located in over thirty prospective habitat areas surveyed.

The Macquarie Pass population is highly vulnerable because of its high elevation and isolation from other populations. It may be the last remnant of a once-larger Illawarra population that occurred along the escarpment and up onto the southern highlands. This population has been subject of a translocation and captive-breeding program. The high altitude population at Mt Werong East is a breeding population but chytrid infected animals were found at there in 2005; chytrid was not detected at Mt Werong West.

### **Population Threats to *M. balbus***

The decline of *M. balbus* at higher elevations in the Greater Sydney Basin appears to mimic the decline of many other Australian frogs (Gillespie & Hines, 1999). It is not known whether high-altitude population losses are due to increased susceptibility to chytrid infections or to some related factor associated with elevated UV-B levels at higher elevations (M. Mahony, pers. comm.). The presence of chytrid in the Mt Werong East population is of great concern as this population (and the Mt Werong West population) are isolated from other extant populations. Regular monitoring of this population is advised to assess the impact of chytrid on the population and to determine the likelihood of long-term survival of the two populations.

Some habitats have changed as a result of agricultural activity in the area. This is especially evident in the Wollombi area where widespread clearing of forest for agriculture has reduced streamside vegetation to narrow strips where the canopy is no longer continuous and water flow has been altered so that flooding no longer occurs downstream. These changes in land use reduce the incidence of water entrapment in the upper catchments, thus reducing the size and number of water pools and riffles (Lewis, 2000) required for

breeding (Mahony *et al.*, 1997b). Laboratory studies (Green *et al.*, 2004) found that pulses of suspended sediment did not adversely affect breeding by the Stuttering Frog. However, this finding does not resolve potential impacts resulting from land clearing or timber gathering. *Mixophyes balbus* does not occur in areas where the riparian vegetation has been disturbed or where there has been significant human impacts upstream (Mahony *et al.*, 1997b).

Eleven out of the 18 extant populations of *Mixophyes balbus* occur in areas close to past or present forestry activities. This suggests that current forestry practices may not be adversely affecting *M. balbus*, however, this study did not undertake detailed habitat assessments and cannot readily adequately identify impacts (if any exist).

*Mixophyes balbus* tadpoles are relatively slow growing and have a long duration in small streams (Anstis, 2002). Fish occur in many of these streams and the tadpoles co-exist with native fish species and may have survival strategies to avoid predation by them (Gillespie & Hero, 1999). However, *M. balbus* has disappeared from many streams where exotic fish, such as trout, carp and *Gambusia* are present (Knowles & Mahony, unpublished data). The extent of tadpole predation by non-native fish is not documented but may be a contributing factor to their decline.

### Long-term Conservation of *M. balbus* in the Sydney Basin

*Mixophyes balbus* has undergone major reduction in distribution in the northern Sydney Basin and is now confined to small regional areas in the Watagan Mountain block, the southern Blue Mountains and Macquarie Pass.

Reasons for the reduction in distribution of this species cannot be completely resolved. There is evidence that changes to land use, particularly clearing has had an impact on frog habitats, but other aspects of the loss of frog habitats are not clear. In particular, the altitudinal patterns of loss cannot be satisfactorily explained.

The conservation of *M. balbus* in the Sydney Basin appears to depend on the conservation of high elevation and low elevation closed forest along riparian corridors. There is no evidence that recent forestry practices have a negative impact on the frogs (Lemckert & Morse, 1999). The recent declaration of the Watagan National Park may have an important conservation role for the ultimate protection of this species. However, intervention may be required to protect particular populations, especially those isolated by distance or unsuitable habitat.

In 2004, tadpoles from the Macquarie Pass population were collected and have been maintained as a captive population in Victoria. This was carried out as the two southernmost populations of *M. balbus* in New South Wales were found to be infected with chytrid and disappeared shortly afterwards; the Macquarie Pass frogs had become the southernmost, uninfected population known (G. Gillespie, pers. comm.). While the exact cause of the decline of Stuttering Frogs at the southern end of their range remains unrecognized, the collection and rearing of representatives of wild populations is regarded as an "insurance" measure should the remaining wild populations also fail. However, if wild populations continue to disappear, even this measure may not be sufficient.

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# OBSERVATIONS OF EGG-ATTENDANCE IN THE ORNATE NURSERY FROG *COPHIXALUS ORNATUS* (MICROHYLIDAE)

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## ABSTRACT

Egg-attendance in two male Ornate Nursery Frogs *Cophixalus ornatus* was monitored for a two and a five month period in lowland rainforest. Clutch size varied from 8 to 24 eggs (mean = 13.8,  $n = 22$ ) that took 30 - 48 days to hatch (mean = 38.8,  $n = 7$ ). Male attendance of simultaneous multiple clutches was recorded: two clutches ( $n = 1$ ), three clutches plus hatchlings ( $n = 1$ ) and four clutches ( $n = 1$ ). Hatching success was 100% when males attended ( $n = 8$ ) but 0% when eggs were abandoned ( $n = 3$ ). Dispersal of hatchlings from oviposition sites varied from 1 - 3 weeks. Other incidental records of egg attendance are described.

## INTRODUCTION

The Ornate Nursery Frog *Cophixalus ornatus* is the most widely distributed of the Australian microhylids, found throughout much of the Wet Tropics region of far north Queensland and encompassing a broad altitudinal range (McDonald, 1992: 22). Only recently have details of its life history, such as chorusing behaviour and mate choice, been the subject of detailed studies (Brooke, 1996; Felton, 1999; Brooke *et al.*, 2000; Hauselberger & Alford, 2005; Felton *et al.*, 2006) though many aspects of its biology remain poorly known. Of the few *Cophixalus* species for which observations are available, the male, female, or both parents remain with eggs (Menzies, 2006: 170-172). In *C. ornatus* it is the male that remains with the eggs (Hoskin, 2004) though precisely how this attendance enhances egg survival is unclear. In this work, I describe field observations of two male *C. ornatus* attending multiple clutches of eggs over a two and a five month period, along with other field observations of *C. ornatus* with eggs.

## METHODS

Observations occurred in a small lowland (40 m asl) rainforest gully at Upper Daradgee (17°32'S 145°55'E), 18 km west of Innisfail (Mena Creek topographic map 1: 50 000, R733, Sheet 8062 1, Ed 2 AAS 1982), north Queensland from September 2005 to November 2007. Habitat was an approximately 70 m wide strip of mesophyll vine forest (Tracey, 1982: 113) on red clay soils with numerous, mostly small basalt stones, abundant leaf litter and small rotting logs. The vegetation in the gully is regenerating after being severely damaged by Cyclone Larry (20.iii.2006) when much of the canopy was removed. All *C. ornatus* at this locality were located beneath stones by day. Digital photographs of males on each visit were used to confirm the identity of individuals by examination of the dorsal colour/pattern, tubercles and skin folds. Measurements of hatchling and adult frog snout-urostyle lengths (SUL) were made with a vernier calliper (to the nearest 0.1 mm). Stone size (maximum linear dimensions) was measured using a flexible tape measure to the nearest 5 mm. Rainfall was recorded by a rain gauge situated less than 100 m from the site and was usually checked daily. The lack of external (i.e., secondary) sexual characteristics of Australian microhylids (Hoskin, 2004) meant that the sex of male frogs was verified by night-time surveys when males were observed calling near oviposition sites; sex of females could only be verified by the presence of eggs visible through skin in the inguinal region. Clutches were described as 'early'-term if there were no visible signs of development and eggs were uniform white; 'mid'-term clutches showed visible signs of development such as eye-spots and limb-buds but lacked dark pigment, while 'late'-term refers to

clutches in which hatchlings had well developed limbs and were darkly pigmented. The term 'attendance' is used throughout instead of 'guarding' since no active defence of eggs/hatchlings was observed, or has yet, been demonstrated in this species. Adult frogs were described as attending eggs if they were located in contact with or were a short distance from eggs. Clutches were denoted by the letter 'C' and a number to indicate their order within the series attended by a particular male, e.g. C4. Additional observations of males with eggs that were not regularly monitored were made at the same site and at several other sites in the region.

## OBSERVATIONS

Observations of two male *C. ornatus* (denoted Male A and B) occupying the same daytime refuge are presented in Tables 1 and 2.

(i) Male A (SUL = 17.5 mm) was located beneath a 350 x 350 mm stone on sloping ground on 12.vi.2006 with a clutch of recently laid eggs ( $n = 15$ ; C1, Table 1). A total of seven clutches were attended over a period of five months, up to three simultaneously, plus hatchlings from a fourth clutch (Table 1). At one stage the male was attending eggs beneath separate but adjacent stones. It is presumed that C7 was eaten since there was insufficient time (max. 9 days old) for the eggs to have fully developed and hatched and there was no evidence of oophagy (i.e., the male did not exhibit any obvious weight gain or distension). The male was observed in direct contact with eggs for 3 of the 12 observations (25%).

(ii) Male B (SUL = 20.2 mm) was located beneath a flat 360 x 320 mm stone on flat ground in the bed of an ephemeral (wet season) stream on 4.viii.2007 with a clutch of recently laid eggs ( $n = 12$ ; C1, Table 2). Subsequent observations took place over two months during which time the male occupied the same daytime retreat without exception and attended a total of two clutches simultaneously (Figure 1). The male was observed in direct contact with either eggs or hatchlings

on 5 of 8 observations (63%).

A third male was monitored over a six-week period but it was only observed attending a single clutch on a few occasions and resided beneath a separate but adjacent rock by day (Male L, Table 3; see below). Whenever it was in attendance it was straddling the egg mass.

Additional observations of *C. ornatus* attending eggs are given in Table 3 however there was little or no monitoring of these clutches. In three instances gravid females were present during daylight hours indicating that oviposition does not always occur immediately after they accompany males back to the nest (Table 3). In a separate instance a gravid female was located within a few centimetres of a male at night and on subsequent inspection the next day, a clutch of eggs was found but neither adult could be located.

## Clutch sizes

A total of 22 clutches from ten different males were recorded ranging in number from 8 to 24 eggs with mean 13.8 eggs ( $sd = 3.89$ ), though it is noted that multiple clutches attended by the same male (i.e., Males A, B and M) may not be independent. The mean clutch size is consistent with that of Felton *et al.* (2006: mean = 14,  $n = 27$ ) but not with Hoskin (2004) whose mean clutch size of 9.5 eggs ( $n = 12$ ) is considerably smaller.

## Egg manipulation and movements

Indirect evidence indicates that males had been in contact with all egg masses: freshly laid clutches of eggs were observed to have perfectly clear and transparent egg capsules and off-white yolks. However subsequent observations indicated that eggs had been smeared in a thin coating of clay that made the capsules translucent rather than transparent. It was also apparent that eggs had been moved short distances ( $< 50$  mm) on several occasions. This sometimes occurred when males had multiple clutches and involved the movement of an entire clutch closer to another so as to form a single egg mass.



## Egg attendance and hatching success

Male A (Table 1) attended eggs on 11 out of 13 observations (85%). Male B (Table 2) attended eggs on 7 out of 8 observations (88%). Male L (in Table 3) was in attendance on only one (the first) out of 5 observations (20%) but resided beneath an adjacent stone only 0.1 m from the clutch. Clutches took between 30 and 48 days (mean = 38.8,  $n = 7$ ) to hatch (Table 4) and hatching success was 100% when males were in attendance. In three clutches that were abandoned egg mortality was 100%. Eggs in these clutches showed apparently normal development and embryos were alive days after being abandoned but were observed to dehydrate over a period of 1–2 weeks.

## Hatchlings

Hatchlings exhibited considerable variation in colouration and pattern both within and between clutches. They were generally darker than adults and many had extensive regions of white flecking on face, ventral surfaces, groin and upper surfaces of the rear limbs. Pale vertebral stripes and other bilaterally symmetrical markings were evident on the dorsal surface of most hatchlings. Hatchlings had an average SUL of 5.5 mm ( $n = 4$ ). Most hatchlings did not immediately disperse from oviposition sites but instead this occurred over a period of 0–3 weeks: 0–1 week ( $n = 4$ ), 1–2 weeks ( $n = 2$ ) and 2–3 weeks ( $n = 1$ ). The latter dispersal time occurred during a dry spell in September (Table 2). On several occasions when the substrate was dry, hatchlings were observed clustered around the male and/or clustered around each other in direct body contact.

## Other fauna beneath stones

Few invertebrates were encountered beneath stones where males were attending eggs. Occasionally ants, Scorpions *Liocheles* sp. and small Whistling Spiders *Phlogiellus* sp. were present. Small ground skinks (mainly *Saproscincus tetradactyla*) were also occasionally present beneath stones with *C. ornatus* eggs.

## DISCUSSION

The breeding season for *C. ornatus* extends from September to February (Felton *et al.*, 2006) and October to March (Brooke *et al.*, 2000) based on studies conducted at an upland site (Paluma, 980 m asl). This period broadly corresponds to the late dry season and the wet season. In this work at a low altitude site (40 m asl), eggs were located outside of these periods, specifically in the months May ( $n = 1$ ), June ( $n = 1$ ), July ( $n = 2$ ) and August ( $n = 3$ ). The species is most vocal throughout the wet season at the low altitude site suggesting that breeding takes place also during this period. Two clutches of eggs were almost certainly deposited in March (from Males H and I) which was the wettest month of that year. However apart from these, *C. ornatus* eggs were not found beneath stones in the gully during the wet season indicating either that breeding ceases during this period (which would seem unlikely given frequent vocalisation), or that different oviposition sites may be used. Male *C. ornatus* were always vocal after rain throughout the year but ceased calling during protracted dry spells (during the months September to December); humidity and social facilitation have been demonstrated to be significant in initiating calling in this species (Brooke *et al.*, 2000; Hauselberger & Alford, 2005). Altitude might explain the difference in the length of the breeding season observed between this and previous studies since year-round higher temperatures and rainfall at the low altitude site are likely to favour reproduction in *C. ornatus* and so extend the length of their breeding season.

Previous studies have indicated that males construct nests (Felton *et al.*, 2006). However, I only found evidence of possible modification of the substrate beneath stones where eggs were deposited in two instances. In both instances the clay substrate appeared to have been modified to provide an 'access' path from the eggs to the outside of the stone. In no instance was there an excavated chamber for eggs nor were eggs covered by any materials.

**Table 1. Chronology of egg-attendance in a male Ornate Nursery Frog *Cophixalus ornatus* (Male A in text) from Upper Daradgee in the latter half of 2006.**

Date	Clutch Size/ Stage	Male Attendance	Substrate	Recent Rainfall	Comments
12.vi.2006	C1 = 15 Early	Yes; several cm from clutches	Moist	86 mm 3 days prior	
30.vii.2006	C1 = 15 Late C2 = 9 Late C3 = 13 Mid	Yes; closest to C2 and C3	Moist	2 mm past week 120 mm since last inspection	Clutches in three separate clumps
6.viii.2006	C1 hatched; 10 hatchlings C2 = 9 Late C3 = 13 Mid C4 = 19 Early	Yes; several cm from clutches	Moist	58 mm 10 days prior	Clutches in two separate clumps 0.14 m apart
13.viii.2006	No C1 hatchlings C2 hatched; 8 hatchlings C3 = 13 Late C4 = 19 Early	Yes; several cm from clutches	Wet	17.5 mm 2 days prior	Hatchlings clustered around eggs
21.viii.2006	C3 hatched; 10 hatchlings C4 = 19 Mid	No; could not be located	Wet	9.5 mm over past week	
27.viii.2006	C3 hatchlings ( $\approx 6$ ) C4 = 19 Late	Yes; straddling C4	Slightly moist	None	Hatchlings clustered around male
5.ix.2006	C4 hatched; 5 hatchlings C5 = 17 Early	Yes; 80 mm from C5	Moist	140 mm previous day	Hatchlings in a clump 15 mm from C5
15.ix.2006	No C4 hatchlings C5 = 17 Early	Yes; near edge of stone	Moist	17 mm previous 2 days	
4.x.2006	C5 = 17 Mid C6 = 24 Early	Yes; several cm from clutches	Dry	15 mm since last inspection	Clutches in a single clump
12.x.2006	C5 = 17 Mid C6 = 24 Early	Yes; straddling C5	Moist	45.5 mm on this day	
19.x.2006	C5 = 17 Late C6 = 24 Mid C7 = 12 Early	Yes; straddling C7	Moist	62 mm on this and previous 2 days	C7 is beneath a separate stone 0.1 m away

Date	Clutch Size/ Stage	Male Attendance	Substrate	Recent Rainfall	Comments
22.x.2006	C5 hatched; ≈10 hatchlings C6 = 24 Late C7 gone	Yes; several cm from C6	Moist	10 mm over last 3 days	Hatchlings clustered around egg remnants
11.xi.2006	C6 hatched; 12 hatchlings	No; could not be located	Dry	5.5 mm over past 2 weeks	
18.xi.2006	No hatchlings or eggs present	No; could not be located	Dry	None	

The observation of males attending simultaneous multiple clutches has been recorded previously in *C. ornatus* (Hoskin, 2004:  $n = 1$ ; Felton *et al.*, 2006: mean = 1.48,  $n = 27$ ). In the instance recorded by Hoskin (2004), a calling male had two clutches of eggs at different stages with two hatchlings of a third clutch also located. I observed one male (A) attending three clutches with hatchlings of a fourth clutch also present and another (Male M) with four clutches of eggs.

Hoskin (2004) recorded that part of a clutch of *C. ornatus* eggs were moved a distance of approximately 40 mm in captivity. I indirectly observed that some clutches of eggs were moved similar distances. There were also clear examples of eggs within clutches having been reorientated. The fact that these eggs subsequently hatched suggests that they tolerate movement during development. In the Papuan species *C. parkeri*, turning of eggs was demonstrated to increase egg survivorship (Simon, 1983) although whether this is also the case for *C. ornatus* is unknown.

Clutch size in *C. ornatus* varies from 3 to 22 eggs ( $n = 1$ , McDonald, 1992;  $n = 12$ , Hoskin, 2004; Felton *et al.*, 2006). A clutch of 24 eggs recorded in this work exceeds the previously recorded maximum clutch size. The hatching times I recorded (30 - 48 days; Table 3) are

slightly longer, but otherwise similar to the 4 - 6 weeks recorded by Felton *et al.* (2006). The lower mean clutch size recorded by Hoskin (2004), however, is of interest given that all small clutches in the sample were from lowland island populations.

In this work the time taken for hatchlings to disperse from beneath stones was up to 3 weeks whereas 2 - 3 days was recorded for hatchlings to leave the oviposition site by Felton *et al.* (2006). In *C. parkeri*, hatchlings stayed at the oviposition site for 30 - 40 days to facilitate absorption of the abdominal yolk mass (Simon, 1983). The dispersal of hatchling *C. ornatus* appeared to be mediated by rainfall: hatchlings tended to disperse quickly (< 1 week) when there was substantial rainfall, but tended to stay at the oviposition site longer when there was little or none. The observations of hatchlings clustering around the male during dry periods may also represent a form of post-hatching parental care, though further observations are needed to confirm this. No observations occurred of males assisting in hatchling dispersal as has been recorded in two Papuan species of related microhylids (Bickford, 2002).

While it seems likely that the presence of the male enhances egg survival, precisely how this is achieved is unclear. In most instances,



**Table 2. Chronology of egg-attendance in a male Ornate Nursery Frog *Cophixalus ornatus* (Male B in text) from Upper Daradgee in 2007.**

Date	Clutch Size/ Stage	Male Attendance	Substrate	Recent Rainfall	Comments
4.viii.2007	C1 = 12 Early	Yes; several cm away	Moist	5.5 mm over last 4 days	Eggs in soil cavity with opening at edge of stone
20.viii.2007	C1 = 12 Mid C2 = 15 Early	Yes; straddling C1	Moist	31 mm over last 4 days	
26.viii.2007	C1 = 12 Mid C2 = 15 Early	Yes; straddling both C1 and C2	Slightly moist	<10 mm over last week	
2.ix.2007	C1 = 12 Late C2 = 15 Mid	Yes; straddling all of C2; part of C1	Moist	44.5 mm over last week	Movement of egg mass had occurred
9.ix.2007	C1 hatched- 9 hatchlings C2 = 15 Mid	Yes; in contact with only 2 eggs & several hatchlings	Dry	16 mm over 3-7.ix	Male was lying prostrate
16.ix.2007	C1- 10 hatchlings C2 = 15 Mid	Yes; hatchlings clustered around male beside C2	Dry	None	Male was lying prostrate
23.ix.2007	C1- 6 hatchlings C2 = 15 Late	Yes; not in contact with C2	Dry	None	Hatchlings scattered; gravid female present
28.ix.2007	C2 hatched; ≈10 hatchlings	No; could not be located	Dry	None	Hatchlings in a single cluster
5.x.2007	No eggs or hatchlings	Yes	Slightly moist	27 mm over last week	

protection from predators, hydration, and the inhibition/removal of pathogens seem to be the most important functions of attendance (Bickford, 2004; Croshaw & Scott, 2005; Lauer *et al.*, 2007). In the three instances where males abandoned eggs, clutches perished while simultaneously those with attendant males did not. These observations

suggest that males have a role in assisting egg hydration. Desiccation has been shown to be a significant source of egg mortality in an arboreal microhylid with male egg-attendance and more generally amongst amphibians with terrestrial eggs (Crump, 1995: 526; Bickford, 2004).

**Table 3. Further records of egg-attendance in Ornate Nursery Frogs *Cophixalus ornatus*.**

Male	Date & Location	Stone Size (mm)	Clutch Size/Stage	Male Attendance	SUL (mm)	Substrate	Rainfall
C	17.x.1999 Seymour Range <sup>a</sup>	-	15 Late	Yes; direct contact with eggs	-	Dry	Last rain was on 8.x
D	14.xii.1999 Goold Is. <sup>b</sup>	-	8 Early	No; gravid female <5 cm from eggs	-	Dry	Last rain about 1 week ago
E	15.x.2006 Daradgee	365 x 185	15 Early	Yes; direct contact with eggs; gravid female present	M 19.4, F 23.2	Moist	64.5 mm over last 4 days
F		310 x 170	16 Early	Yes	18.4	Moist	
G		370 x 115	12 Early	Yes	17.9	Moist	
H	1.iv.2007 Daradgee	250 x 200	22 Mid	Two adults present; sexes unknown	-	Moist	25 mm on 28.iii
I		340 x 235	9 Early	Yes; egg string draped over mid-body	-	Moist	
J	12.v.2007 Daradgee	320 x 195	10 Early	Yes; straddling eggs	-	Wet	≈20 mm over last 2 days
K	21.viii.2007 Daradgee	290 x 150	≈10 Early	No; adult (male?) and gravid female present previous evening	-	Slightly moist	51.5 mm over last week
L	2.ix.2007 Daradgee	175 x 110	14 Early	Yes; straddling eggs	19.6	Moist	30.5 mm over last 3 days
M	20.vii.2008 Daradgee	200 x 170	4 clutches: 12, 11, 13, 16; Early to Mid	Yes; straddling eggs	20.1	Moist	96.5 mm over last 5 days

<sup>a</sup>17°29'S 146°03'E, ≈60 m asl. Cooper Point topographic map 1:50 000 (R733, Sheet 8163 3, Ed 1 AAS 1986)

<sup>b</sup>18°10'S 146°10'E, 100-150 m asl. Rockingham Bay topographic map 1:50 000 (R733, Sheet 8163 3, Ed 1 AAS 1987)

**Table 4. Clutch size, hatching success/time and male attendance in thirteen clutches of eggs in the Ornate Nursery Frog *Cophixalus ornatus*.**

Male/Clutch	Clutch size	Hatching Success (%) (days)	Approximate Hatching Time	Male Attendance
<b>Male A (Table 1)</b>				
C1	15	100	48	Yes
C2	9	100	-	Yes
C3	13	100	-	Yes
C4	19	100	30	Yes
C5	17	100	47	Yes
C6	24	≈60	38	Part
C7	12	0	-	Part
<b>Male B (Table 2)</b>				
C1	12	100	36	Yes
C2	15	100	38	Yes
<b>Males (Table 3)</b>				
L	14	100	35	Part
F	16	0	-	Abandoned
I	9	0	-	Abandoned
K	≈10	0	-	Abandoned

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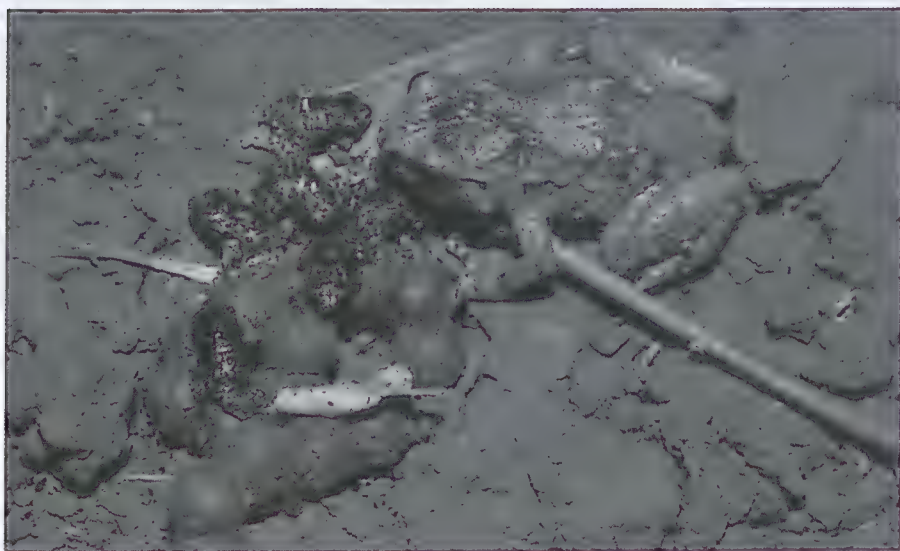
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**Figure 1. Photograph of a male Ornate Nursery Frog *Cophixalus ornatus* (Male B) *in situ* beside a mid-term clutch of 15 eggs and 9 hatchlings from an earlier clutch of 12 eggs (see Table 2 for details).**



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# OBSERVATIONS OF SNAKE PREDATION ON THE PYGMY BLUETONGUE LIZARD, *TILIQUA ADELAIDENSIS*

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## INTRODUCTION

The Pygmy Bluetongue Lizard, *Tiliqua adelaidensis*, is a small (SVL 95 mm), endangered scincid lizard found in remnant fragments of native grasslands in the mid north of South Australia (Armstrong *et al.*, 1993; Hutchinson *et al.*, 1994). There were no recorded collections of this species from 1960 until 1992 and by that time it was thought to be extinct (Ehmann, 1982; Cogger, 1992). However, in 1992 a Pygmy Bluetongue Lizard was recovered from the stomach of a recently road-killed Eastern Brown Snake, *Pseudonaja textilis* (Armstrong & Reid, 1992). Live specimens were subsequently found occupying burrows constructed by lycosid and mygalomorph spiders which they use for both shelter and vantage points for ambushing passing prey (Hutchinson *et al.*, 1994; Milne *et al.*, 2003). Both field observations and experimental studies suggested these lizards prefer deep burrows with an entrance no wider than the head width of the lizard (Hutchinson *et al.*, 1994; Milne & Bull, 2000; Milne *et al.*, 2003). Hutchinson *et al.* (1994) found that when an occupied burrow was inspected with an endoscope, the lizard often tilted its head down against the burrow wall, exposing only the hard armoured top of the head. They suggested that lizards blocked the burrow in this way to prevent predator from grasping, dislodging or attacking the occupant in the burrow. Milne and Bull (2000) also reported foxes digging at known Pygmy Bluetongue burrows. In some instances, the burrow was not fully excavated and the resident lizard was still present. These examples highlight the importance of burrows as refuges from predators for Pygmy Bluetongue Lizards. Further obser-

vations of tail damage to Pygmy Bluetongue Lizards by avian predators (Fenner *et al.*, 2008) suggested they are most vulnerable to predation while moving around on the surface.

This paper reports three observations of interactions between Pygmy Bluetongue Lizards and one natural predator, the Eastern Brown Snake, *Pseudonaja textilis*. They contribute to understanding the potential impact of snakes on this endangered species.

## THE PREDATOR

The Eastern Brown Snake, *Pseudonaja textilis*, is a slender, fast moving elapid that may reach two metres in total length (Cogger, 1992). Eastern Brown Snakes are active, generalised predators of small vertebrates, such as House Mice, *Mus musculus*, in agricultural cropping areas, but they prey on reptiles and amphibians in less disturbed areas (Shine, 1977, 1989; Whitaker & Shine, 2003).

## STUDY SITE

The observations all took place in semi arid grassland near Burra (33°41'S 138°56'E), in South Australia. The site contained tussocks of native and exotic tussock grasses with a small rocky creek that flows only after heavy rain (Hutchinson *et al.*, 1994; Milne, 1999).

## OBSERVATIONS

On 12 October 2006 at 0934 hrs, a mature Eastern Brown Snake was observed with its head approximately 8 cm into a burrow. The entrance dimensions of the burrow were typical of those used by Pygmy Bluetongue Lizards. The snake remained like this for

approximately five minutes. During this time it appeared to tense up and thrash around frequently, as though it was trying either to pull something out of the burrow or to force its way deeper into the burrow (although it achieved neither of these). The snake had first entered the burrow prior to our arrival, so we could not estimate how long these activities lasted. When the snake emerged, it did not appear to have anything in its mouth. We did not record whether a lizard was in the burrow either before or after the snake visit, but the observation shows that Eastern Brown Snakes will enter spider burrows in search of prey.

A second interaction was filmed on 7 October 2007 at 0930 hrs with a CCTV camera and digital video recorder. As part of a separate behavioural study, a life-size, plastic model of a Pygmy Bluetongue Lizard had been placed in front of an occupied lizard burrow, with the camera above the burrow entrance. The recording showed an Eastern Brown Snake entering from the top of the frame about 60 cm from the model. It approached the model directly and then rapidly struck at the model on the nape of the neck. The snake then tongue flicked rapidly along the length of the model. It appeared to realise that the object was not edible and moved out of the bottom of the frame, without inspecting the burrow containing the live lizard. This observation suggested that Eastern Brown Snakes can recognize potential prey from stationary visual cues.

The third interaction was filmed on 7 November 2007 at 1022 hrs during the same behavioural study. A gravid, adult female Pygmy Bluetongue Lizard occupied the burrow that was being filmed. The lizard emerged from its burrow and moved towards the bottom left of screen, in pursuit of a passing grasshopper. The lizard had only its tail remaining in the burrow when an Eastern Brown Snake entered from the top right of screen (Figure 1). The snake appeared to see the lizard as it started to reverse back into its burrow. The lizard had its hind legs and most of the body into the burrow when the snake

struck at the neck and grasped it behind the head (Figure 2). The snake held onto the lizard and tried to pull it out of the burrow. The lizard meanwhile tried to pull itself backwards down into the burrow to escape the snake's grasp. This struggle continued for seven minutes until the lizard was either killed or seriously impaired by the snake venom. The snake then dragged the lizard out of its burrow, and commenced ingesting it head first (Figure 3). The lizard was consumed in two minutes. The snake then left the filmed area, but returned after 42 seconds and inspected the model Pygmy Bluetongue Lizard. It tongue flicked up and down the length of the model for a few seconds (Figure 4). It then moved to the burrow entrance, placed its head at the burrow entrance and tongue flicked into the entrance. It then opened its mouth in a "yawn" and then moved out of frame again. Due to the time frame between observations and their locality within the lizard population (> 500 m apart) (Whitaker & Shine, 2003), it is unlikely that the same snake was involved in more than one observation.

## DISCUSSION

The three observations provide important information about the interaction between Eastern Brown Snakes and Pygmy Bluetongue Lizards. Snake predation was a fortuitous component in the rediscovery of the lizard, and may play a significant role in its population dynamics. For effective conservation management we need to be aware of all potential threats to population persistence.

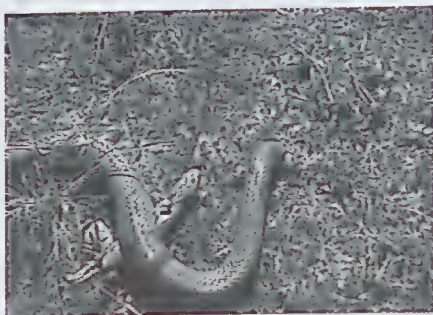
The first observation showed that Eastern Brown Snakes will enter lizard burrows in search of prey. Lizards in burrows will be vulnerable to snakes if the burrow is too shallow or too wide. Other studies have shown that the choice of an optimal retreat site can reduce the vulnerability of reptiles to predators (Jackson, 1988; Schlesinger & Shine, 1994; Milne *et al.*, 2003). In our first observation the snake that entered the lizard burrow was not successful. Although we



**Figure 1. Position of pygmy blue-tongue lizard as eastern brown snake approaches.**



**Figure 2. Eastern brown snake moments after strike, grasping the pygmy bluetongue lizard by the head.**



**Figure 3. Eastern brown snake swallowing and removing the pygmy bluetongue lizard from its burrow.**



**Figure 4. Eastern brown snake returning after consuming pygmy bluetongue lizard to inspect the model.**



cannot claim this as evidence that a burrow of sufficient depth and tightness will protect the lizard from snake predation (Hutchinson *et al.*, 1994; Milne, 1999; Milne & Bull, 2000), it is a possibility that warrants further examination.

The second observation of a snake striking a motionless, unscented model, showed the shape of a lizard is sufficient to elicit an attack. This suggests that Pygmy Bluetongue Lizards are vulnerable to snake predation when they are out of their burrows, even if they remain motionless.

The third observation showed a lizard being captured by a snake within less than a body length of its burrow. We do not know if the gravid state of the female lizard hindered its retreat into the burrow, but in this case the snake struck too quickly for the lizard to escape. Thus, Pygmy Bluetongue Lizards are vulnerable to predation by snakes even if they are only partially emerged from their burrow. Since lizards emerge from their burrows to bask and to capture prey themselves (Milne *et al.*, 2003), they are regularly exposed to predation risk.

These three observations show the importance of burrows, and the selection of suitable burrows, for Pygmy Bluetongue Lizard survival. They provide evidence of the vulnerability of Pygmy Bluetongue Lizards to snake predation and demonstrate how even simple activities such as basking, put them at risk. Greater exposure from moving in the open to feed or search for mates will put the lizards at greater risk of predation by snakes. The observations also contain lessons for conservation management of this species. Conservation actions that involve outdoor breeding colonies or translocations with temporary holding areas (Hein & Whitaker, 1997; Plummer & Mills, 2000; Sullivan *et al.*, 2004; Butler *et al.*, 2005; Rittenhouse *et al.*, 2007) should ensure that enclosures are snake proofed. In addition, translocated reptiles are often less settled, moving more and choosing less optimal shelter sites than residents, and can remain so for up to two years after the translocation (Reinert & Rupert, 1999).

## ACKNOWLEDGMENTS

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# NOTES ON REPRODUCTION OF *CARLIA EOTHEN* AND *LAMPROLEPIS SMARAGDINA* (SQUAMATA: SCINCIDAE) FROM PAPUA NEW GUINEA

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## INTRODUCTION

Information on reproduction in Pacific skinks is sparse, with most existing information being from the genus *Emoia* (Baker, 1947; Alcalá & Brown, 1967; Schwaner, 1980; Auffenberg & Auffenberg, 1989; Goldberg & Kraus, 2008a). However, information is also available for *Carlia bicarinata* and three species of *Sphenomorphus* from New Guinea (Zug et al., 1982; Goldberg & Kraus, 2008b) and several species of skinks from the Philippines (Alcalá, 1966; Auffenberg & Auffenberg, 1989). These data indicate that reproductive strategies in these skinks can be diverse, and this variation may correlate with seasonal moisture availability. However, sampling across taxa, geographic regions, and climatic regimes needs to be improved before a link between reproductive strategy and seasonality can be accepted with confidence.

*Carlia* is an Australopapuan-Lesser Sunda genus of skinks of which three species groups, the *bicarinata*, *fusca* and *novaeguineae* groups occur in New Guinea (Zug, 2004; Kraus, 2007). Zug (2004) revised the members of the *Carlia fusca* group, dividing that taxon into 14 species, with two additional members described subsequently (Zug & Allison, 2006). Among these newly recognized species, *C. eothern* occurs in eastern Papua New Guinea throughout Milne Bay Province, including its outlying island groups: D'Entrecasteaux, Trobriand, Woodlark, and Louisiade islands (Zug, 2004). *Lamprolepis smaragdina* is widespread in Oceania and occurs from Taiwan, the Philippines, and Lombok south and east through Micronesia, the Indo-Australian Archipelago, New Guinea and Cape York (Australia) to the Solomon Islands and the Santa Cruz Islands

(Greer, 1970). It has also been introduced to the Mariana Islands (Eldridge, 1988; Rodda et al., 1991). *Lamprolepis smaragdina* has also recently been reported from islands of Milne Bay Province, Papua New Guinea: Misima, Normanby, and Woodlark (Kraus & Allison, 2004), as well as Nimowa and Sudest (Kraus & Shea, 2005). We know of no reports detailing the reproductive biology of *Carlia eothern*. There is information on reproduction in captive *Lamprolepis smaragdina* (Peters, 1985; Rogner, 1997) and from wild Philippine populations (Alcalá, 1966; Auffenberg & Auffenberg, 1989) as well as a report of clutch sizes from the Solomon Islands (McCoy, 2006).

The purpose of this paper is to report information on reproduction in *C. eothern* and *L. smaragdina* from a histological examination of gonads from museum specimens so as to improve the pool of reproductive information available for Pacific skinks. Comparisons are made with reproductive cycles of other scincid lizards from Oceania.

## MATERIALS AND METHODS

Thirty-eight *C. eothern* (17 females, mean snout-vent length, SVL = 52.6 mm  $\pm$  3.9 SD, range = 47-59 mm; 14 males, SVL = 54.7 mm  $\pm$  7.1 SD, range = 41-63 mm; 7 neonates, SVL = 24.6 mm  $\pm$  2.4 SD, range = 21-28 mm) and eight *L. smaragdina* (5 females, SVL = 98.4 mm  $\pm$  4.7 SD, range = 91-103 mm; 3 males, SVL = 97.0 mm  $\pm$  8.2 SD, range = 88-104 mm) from Milne Bay Province, Papua New Guinea were examined from the herpetology collection of the Department of Natural Sciences, Bishop Museum, Honolulu, Hawaii (Appendix).

Skinks were collected 2002 to 2004 as part of biodiversity surveys and were studied from a geographically limited region (Milne Bay Province) so as to minimize the potential for geographic variation to confound interpretation of reproductive cycles. Survey schedules disallowed comprehensive sampling throughout the year but were sufficiently spaced in time to allow some inference of yearly reproductive patterns. The left gonad was removed, dehydrated in ethanol, embedded in paraffin, sectioned at 5  $\mu$ m and stained with Harris hematoxylin followed by eosin counterstain (Presnell & Schreibman, 1997). Enlarged follicles (> 4 mm length) and oviductal eggs were counted. Histology slides were deposited in the Vertebrate Collection, Bishop Museum. Male and female mean body sizes (SVL) were compared with an unpaired *t* test using Instat (vers. 3.0b, Graphpad Software, San Diego, CA).

## RESULTS

*Carlia eothen*: There was no significant size difference between female and male mean body sizes (SVL), *t* = 1.03, *df* = 29, *p* = 0.30. Three stages were observed in the testicular cycle of *C. eothen*: (1) In recrudescence, the germinal epithelium is renewed for the next period of sperm formation (spermiogenesis). There is a proliferation of germ cells. In early recrudescence, primary spermatocytes predominate; in late recrudescence, secondary spermatocytes and spermatids predominate. (2) In spermiogenesis, the lumina of the seminiferous tubules are lined by spermatozoa. Rows of metamorphosing spermatids are typically observed. (3) In regression, spermatogonia are the predominant cells in the seminiferous tubules.

Males collected in January (*n* = 5), February (1), May (1), August (1), and September (3) were undergoing spermiogenesis. The smallest male to exhibit spermiogenesis (BPBM 16879) measured 53 mm and was collected 11 January. Two males from May that were undergoing recrudescence (BPBM 19934, SVL = 45 mm and BPBM 19935, SVL = 48

mm) and one male from April with inactive testes consisting of mainly spermatogonia (BPBM 19928, SVL = 41 mm) were probably juveniles.

Reproductively active females were present in all months sampled (Table 1): Clutch size for 15 *C. eothen* females was invariably two. The smallest reproductively active female (BPBM 16880) contained two oviductal eggs, measured 47 mm SVL, and was collected in January. One female from January (BPBM 16885) contained two oviductal eggs and concurrent vitellogenesis (yolk deposition) for a subsequent clutch indicating *C. eothen* may produce multiple clutches in the same year. The one September female that was reproductively inactive (BPBM 15894) measured 48 mm SVL and was of sufficient size that she may have been between clutches.

The sample of 38 *C. eothen* included seven presumed hatchlings (21–28 mm SVL) collected in February (*n* = 2), May (1), August (1) and September (3).

*Lamprolepis smaragdina*: The three adult males examined (one each from April, May and September) were reproductively active with spermiogenesis in progress.

Two females from January (BPBM 16858, SVL 91 mm; BPBM 16859, SVL 103 mm) and one from April (BPBM 20005, SVL 102 mm) all contained two oviductal eggs. One female from May (BPBM 20007, SVL 98 mm) was reproductively inactive and was of sufficient size that she may have been between clutches. One female from September (BPBM 15994, SVL 98 mm) contained two enlarged follicles (> 5 mm). Clutch size for all females was uniformly two. One January female (BPBM 16859) with oviductal eggs was undergoing concomitant yolk deposition for a subsequent clutch indicating the likelihood that *L. smaragdina* can produce a second egg clutch in a single year.

## DISCUSSION

Most studies on reproduction in skinks from the Pacific islands have been done on members of *Emoia*. These studies have indicated long periods of reproductive activity with reproduction possible throughout the year (Baker, 1947; Alcalá & Brown, 1967, Schwaner, 1980; Auffenberg & Auffenberg, 1989; Goldberg & Kraus, 2008a). Baker (1947) reported that in the Republic of Vanuatu where *Emoia cyanura* exhibited year-round reproductive activity, there was a peak in November and December. It appears both *C. eothern* and perhaps *L. smaragdina* exhibit prolonged reproductive cycles, although our samples were too small to identify peak periods of activity, if one exists for these species. Hatchlings of *C. eothern* were scattered throughout the year further supporting an extended period of reproduction.

Zug *et al.* (1982) reported that *Carlia bicarinata* near Port Moresby, Papua New Guinea exhibited a seasonal reproductive pattern, in which females were gravid from December to June; yolk deposition commenced in October (Zug *et al.*, 1982). Males exhibited year-round spermiogenesis, with enlarged testis

sizes from September through April. Wilhoft (1963) reported *Carlia* (as *Leiopisma*) *rhomboidalis* exhibited spermiogenesis throughout the year in tropical Australia. Our results may differ from those of Zug *et al.* (1982) for *Carlia bicarinata* because their sample came from a savannah region having a pronounced wet/dry seasonality. In contrast, the rainforests in Milne Bay Province have a less markedly seasonal climate similar to that in the Wet Tropics range of *C. rhomboidalis* studied by Wilhoft (1963). A similar pattern of extended reproduction was reported in five *Emoia* group skinks (*Emoia caeruleocauda*, *E. jakati*, *E. longicauda*, *E. obscura* and *E. pallidiceps*) and three *Sphenomorphus* group skinks (*Sphenomorphus granulatus*, *S. jobiensis* and *S. minutus*) from Milne Bay Province, Papua New Guinea by Goldberg and Kraus (2008a,b).

In the Philippines, Alcalá (1966) reported breeding of *Lamprolepis* (as *Dasia*) *smaragdina* occurred throughout the year and clutch size was two. Also for *L. smaragdina* in the Philippines, Auffenberg and Auffenberg (1989) reported a clutch-size mean of  $1.9 \pm 0.3$  SD (range: 1-2), with gravid females found every month. McCoy (2006) reported

**Table 1. Monthly stages in the ovarian cycle of *Carlia eothern* from Milne Bay Province, Papua New Guinea.**

Month	n	Inactive	Early yolk deposition	Enlarged oocytes (> 4 mm)	Oviductal eggs	Oviductal eggs and yolk deposition
January	6	0	0	4	1	1
February	1	0	0	0	1	0
April	1	0	0	0	1	0
May	4	0	1	1	2	0
August	1	0	0	0	1	0
September	4	1	0	1	2	0



clutches of two eggs for *L. smaragdina* in the Solomon Islands. Our results are consistent with this pattern in the Philippines and Solomons. The smallest *L. smaragdina* female from the Philippines with oviductal eggs measured 83 mm SVL (Auffenberg & Auffenberg, 1989). Our samples did not span a sufficient range of body sizes to allow meaningful comparison of minimum sizes at reproduction between Papua New Guinea and the Philippines data. However, one female with oviductal eggs for a current clutch and concomitant yolk deposition for a subsequent clutch indicate *L. smaragdina* may produce multiple clutches in the same year in Papua New Guinea. In contrast, Alcalá (1966) suggested that in the Philippines one clutch was laid per year. In view of the extensive geographic range of *L. smaragdina*, additional studies are necessary to better assess whether geographic variation occurs in its reproductive cycle.

Auffenberg and Auffenberg (1989) found almost every conceivable type of pattern in their study of reproduction in 11 species of sympatric Philippine skinks representing adaptations to seasonal rainfall; extended periods of egg production appeared typical. It is thus apparent that the reproductive strategies of scincid lizards in Oceania are diverse and their clarification warrants further investigation. In particular, it is important to assess to what extent reproductive variation is explained by seasonal variability in moisture patterns, a possibility suggested by the data currently available for *Carlia* whose constituent species occupy habitats spanning a wide range of climatic regimes (Ingram & Covacevich, 1988, 1989; Zug, 2004). To meet this goal will require collection of additional data from all climatic regimes in the region.

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## APPENDIX

Specimens examined from the herpetology collection of the Bishop Museum, Honolulu, Hawaii, USA.

*Carlia eothen* ( $n = 38$ ): Cloudy Mountains, April 2002 (BPBM 15516); Owen Stanley Mts, Mt Pekopekowana, 300 m, May 2002 (BPBM 15518); Fergusson Island, Basima, August 2002 (BPBM 15888); Fergusson Island, Mt. Kilkerran (Oyatabu), August 2002 (BPBM 15891-92); Fergusson Island, Saibutu, September 2002 (BPBM 15893); Dadue, September 2002 (BPBM 15894-95); Normanby Island, Saidowai, September 2002 (BPBM 15896, 15902, 15904-05), January 2003 (BPBM 16885); Normanby Island, Samoa, September 2002 (BPBM 15898-900); Misima Island, Liak, January 2003 (BPBM 16878-84); Normanby Island, S end Sewa Bay,

January 2003 (BPBM 16886); Normanby Island, along Koyakakapowa River, January 2003 (BPBM 16887-88); Halowia, February 2003 (BPBM 16889-91); Stringer Bay, February 2003 (BPBM 16893); Misima Island, Somusomuwa, April 2004 (BPBM 19928); 9 km W Alotau, May 2004 (BPBM 19929); Normanby Island, Sibonai, June 2004 (BPBM 19930-35).

*Lamprolepis smaragdina* ( $n = 8$ ): Kinahidamadama River, Alotau, April 2002 (BPBM 15583); Fergusson Island, Basima, September 2002 (BPBM 15994); Normanby Island, Saidowai, September, 2002 (BPBM 15995); Misima Island, along Nulia River, Liak, January 2003 (BPBM 16858); Normanby Island, Saidowai, January 2003 (BPBM 16859); Sudest Island, Araeda, April 2004 (BPBM 20005); Nimowa Island, Sofuwu Mission, May 2004 (BPBM 20006-07).



# A HERPETOFAUNA SURVEY OF THE VISY PULP AND PAPER MILL PROPERTY, GILMORE, NSW

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## INTRODUCTION

Documenting the occurrence and abundance of wildlife is a critical part of developing ecologically sustainable strategies for the management of natural resources (Lindenmayer & Burgman, 2005). In Australia, considerable effort has been directed at surveying some groups of vertebrates such as birds (e.g., HANZAB 1990-2006 and references therein) and mammals (e.g., Van Dyck & Strahan, 2008 and references therein). Some areas in particular have been the focus of significant recent survey work. One of these is the South-western Slopes (SWS) of New South Wales - the most heavily altered vegetation region of that state (Benson, 1999). Numerous bird and mammal surveys have taken place in this region (e.g., Reid, 1999; Seddon *et al.*, 2003; Kavanagh *et al.*, 2005; Cunningham *et al.*, 2007, 2008; Lindenmayer *et al.*, 2007, 2008). Far less effort has been expended on surveys of reptiles (see Fisher *et al.*, 2003, 2004, 2005; Michael *et al.*, 2008) or amphibians in the region (see Hunter & Gillespie, 1999; Gillespie & Hunter, 1999). Most reptile studies are one off 'snap shots' and hence due to limited survey effort, underestimate species richness by failing to detect many species potentially occurring in an area (Bos & Lockwood, 1996; Daly, 2004; Lemckert, 1998). Repeated surveys of reptiles over time are extremely rare but are often necessary to sample entire assemblages. For example, Caughley and Gail (1985) found the cumulative number of reptile species increased from 50% after one day to 80% after just 3.5 days of surveying. Additionally, Sass (2003) surveyed six sites for 50 hours over a one year period near Wagga Wagga and recorded an average of 17 species per site, as well as detecting a number of species never or rarely recorded in the bioregion (e.g. Bynoe's Gecko *Heteronotia binoei*, Southern

Death Adder *Acanthophs antarcticus*, Yellow-faced Whip Snake *Demansia psammophis*, Red-naped Snake *Furina diadema* and Eastern Bandy Bandy *Vermicella annulata*). Likewise, Michael (2004, 2007) surveyed a 500 ha site repeatedly in Albury and recorded 24 species over a seven year period. These kinds of studies are invaluable, especially in documenting species previously unrecorded in a region and extending their known ranges. However, repeated long-term reptile surveys are extremely uncommon, but are essential to detect rare and cryptic species as well as threatened and regionally significant taxa. In this paper we report on baseline data from two repeat herpetofauna surveys on a 1100 ha area on the SWS owned by pulp and paper company VISY. We also include comments on an additional record of the enigmatic Broad-palmed Frog *Litoria latopalmata* in the SWS. These preliminary data signify the beginning of a longitudinal study designed to monitor and survey reptile fauna in remnant vegetation and tree plantings on the VISY property over the next decade.

## STUDY AREA

As part of their commitment to environmental monitoring, VISY consulted with The Australian National University to establish a long-term monitoring study of vertebrate fauna on the Gilmore property. The VISY pulp and paper mill is located on a property covering 1100 ha and is situated in the Gilmore Valley, 8 km west of Tumut in the South-western Slopes biogeographical region of NSW. The property ranges in elevation from 300 - 650 metres above sea level and incorporates valley flats, slopes and steep topography. The climate is warm temperate, with average minimum and maximum temperatures ranging from 12 - 29°C in summer and 1 - 13°C in winter (Bureau of Meteorology,

2007). The land was formerly managed as a grazing property and hence, much of the woodland vegetation occurring on fertile soils was cleared and modified with exotic pasture plants. Some native pasture, ephemeral creeks and a wetland still remain. The upper slopes and hills contain partly cleared forest vegetation, abundant fallen timber and small exposed granite outcrops. Since VISY commenced mill operations in 2001, a number of water storage dams have been constructed and native vegetation planted along some of the creek lines and wetland.

## VEGETATION

Two vegetation communities occur on the VISY mill property. On the fertile slopes, Box-Gum woodland, dominated by White Box *Eucalyptus albens*, Blakely's Red Gum *E. blakelyi* and Yellow Box *E. melliodora*, intergrade with dry foothill forest, dominated by Red Stringybark *E. macrorhyncha* and Long-leaved Box *E. goniocalyx* on elevated sites. Cleared areas are dominated by common pasture species such as Barley Grass *Hordeum* sp., Rye Grass *Lolium* sp. and *Phalaris Phalaris* sp. but also include mature scattered paddock trees of various species. The remnant woodland and forest vegetation contain a patchy understorey of Peach Heath *Lissanthe strigosa*, Daphne Heath *Brachyloma daphnoides*, Nodding Blue-lily *Stypanandra glauca* and Prickly Teatree *Leptospermum continentale* growing in gully lines. The tree plantings, established in 2002, include a mixture of local *Eucalyptus* and *Acacia* species.

## METHODS

In the spring of 2006, we established 18 permanently marked survey sites. Ten sites were situated in areas of remnant vegetation and eight sites were situated in tree plantings. Planting sites occurred near the creek, wetland and lower slopes while remnant sites covered lower, upper slopes, ridge lines and the plateau. Sites consisted of a 200 m transect, marked with star pickets at the 0 m, 100 m and 200 m point intervals. Artificial substrates, two sheets of 1 x 1 m corrugated iron sheets (one on top of the other with leaf litter

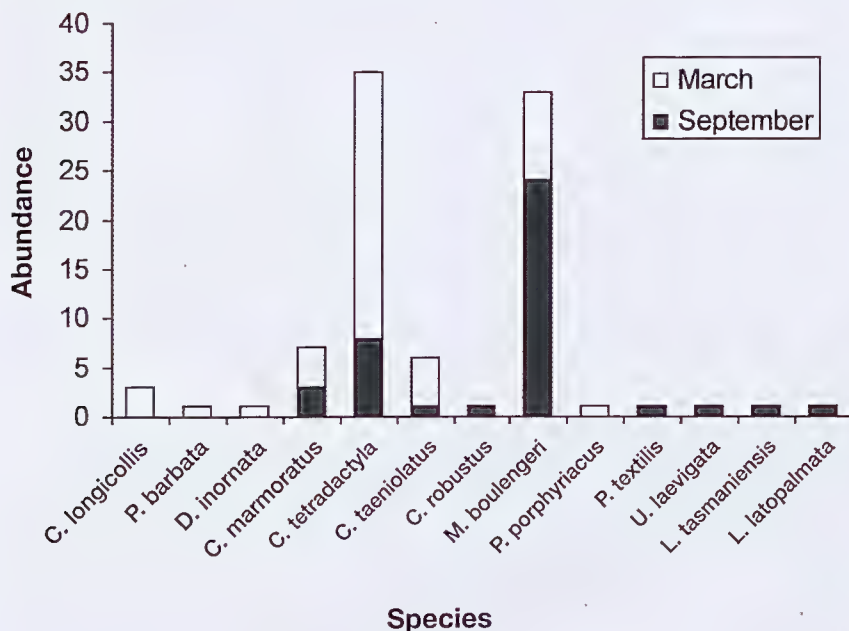
in between) were established at the 0 m and 100 m points. We checked the artificial substrates for sheltering fauna and conducted 20 minute active searches along the transect inspecting all available habits over 1 ha (50 x 200 m). Amphibians and cheluids were not specifically targeted, instead they were recorded opportunistically. Surveys were conducted on 5.iii.2007 and 4.ix.2007 between the hours of 0900 and 1600 hrs. Both days were clear, sunny and reached maximums above 22°C. Species were identified visually or by call in the case of frogs. Additional evidence such as scratch marks of varanid species on smooth trees (varanids leave characteristic indentations that can be distinguished from arboreal marsupials based on the angle, length and depth of claw marks); slough skins, eggs and incidental sightings on the property were recorded.

## RESULTS

We recorded a total of 17 species during both surveys. These included one turtle, eleven reptiles and five frogs, representing nine families and 92 observations (Table 1). The majority of species (70.5%) were recorded from remnant vegetation, while seven species (41.2%) were recorded from tree plantings. Ten species (58.8%) were detected only in remnant vegetation, five species (29.4%) were only detected in plantings, while two species, *Carlia tetradactyla* and *Limnodynastes tasmaniensis*, were recorded in both habitats (Table 1). During the March survey, we recorded 51 individuals belonging to eight species compared with 41 individuals from nine species during the September survey (Figure 1). An additional five species were recorded in the second survey, and only four species were common to both surveys (*Christinus marmoratus*, *C. tetradactyla*, *Ctenotus taeniolatus* and *Morethia boulengeri*; Figure 1).

Two species accounted for over 70% of all observations (Figure 1). The most common species was *C. tetradactyla* which accounted for 38.0% of total observations followed by *M. boulengeri* with 35.9% of observations. These two species differed in their relative abundance between habitats, with more

**Figure 1. Relative abundance of reptiles recorded during the March and September 2007 surveys of the VISY pulp and paper mill, Gilmore, NSW. (Excludes incidental records of *D. vittatus*, *Varanus* sp., *C. signifera* and *C. parinsignifera*).**



observations of *C. tetradactyla* in plantings and more observations of *M. boulengeri* in remnant vegetation. Eight species were observed on one occasion (Table 1) including the regionally significant Broad-palmed Frog *Litoria latopalmata* (Figure 2).

## DISCUSSION

Most species were recorded from the remnant foothill forest sites, although five species were recorded from the native tree plantings (Table 1). Four of these species, *Chelodina longicollis* (detected basking on submerged logs in a dam), *Crinia signifera*, *C. parinsignifera* and *Pseudechis porphyriacus*, are typically associated with riparian environments (Cogger, 2000; Wilson & Swan, 2003) and are therefore more likely to occur in the moister tree planting sites on the VISY property. The other species recorded from plantings was *Ctenotus*

*robustus*. This species was expected to occur in the remnant sites, especially in areas with abundant surface rock and fallen timber (Fisher & Lindenmayer, 2005; Michael *et al.*, 2008) but instead, it was detected near *Phalaris aquatica* tussocks.

*Carlia tetradactyla* and *M. boulengeri* were the most abundant species recorded during the surveys. They are two of the most common heliothermic species in south-eastern Australia (Cunningham *et al.*, 2007; Daly, 2004; Henle, 1998; Fisher *et al.*, 2003). *Morethia boulengeri* can often exceed densities of 1000 individuals per hectare (Henle, 1998). In this study, *M. boulengeri* was only recorded in remnant sites, especially in open grassy areas and in the vicinity of fallen timber, while *C. tetradactyla* was more common in grassy plantings. Both species are known to utilise resources in agricultural areas



**Table 1. Abundance of herpetofauna recorded from VISY pulp and paper mill tree planting and remnant vegetation survey sites, Gilmore, NSW.**

(Values in brackets indicate the number of observations from beneath corrugated iron substrates. Incidentals: H = heard calling, C = claw marks and S = slough skin).

Common Name	Scientific Name	Planting	Remnant
<b>Cheluidae</b>			
Eastern Long-necked Turtle	<i>Chelodina longicollis</i>	3	-
<b>Agamidae</b>			
Eastern Bearded Dragon	<i>Pogona barbata</i>	-	1
<b>Pygopodidae</b>			
Olive Legless Lizard	<i>Delma inornata</i>	-	1
<b>Gekkonidae</b>			
Southern Marbled Gecko	<i>Christinus marmoratus</i>	-	7 (1)
Eastern Stone Gecko	<i>Diplodactylus vittatus</i>		S
<b>Scincidae</b>			
Southern Rainbow Skink	<i>Carlia tetradactyla</i>	27 (1)	8 (2)
Large Striped Skink	<i>Ctenotus robustus</i>	1	-
Copper-tailed Skink	<i>Ctenotus taeniolatus</i>	-	6 (1)
Boulenger's Skink	<i>Morethia boulengeri</i>	-	33 (2)
<b>Varanidae</b>			
Monitor	<i>Varanus sp.</i>	-	C
<b>Elapidae</b>			
Red-Bellied Black Snake	<i>Pseudechis porphyriacus</i>	1	-
Eastern Brown Snake	<i>Pseudonaja textilis</i>		1
<b>Myobatrachidae</b>			
Common Froglet	<i>Crinia signifera</i>	H	-
Plains Froglet	<i>Crinia parinsignifera</i>	H	-
Spotted Marsh Frog	<i>Limnodynastes tasmaniensis</i>	H	1
Smooth Toadlet	<i>Uperoleia laevigata</i>	-	1 (1)
<b>Hylidae</b>			
Broad-palmed Frog	<i>Litoria latopalmata</i>	-	1
<b>Total abundance</b>		<b>32 (1)</b>	<b>60 (7)</b>
<b>Species richness</b>		<b>7</b>	<b>12</b>

(Fisher *et al.*, 2003; Cunningham *et al.*, 2007; Michael *et al.*, 2008) and are likely to respond to grazing and timber management sympathetic to reptile conservation (Brown, 2001).

Five species were recorded infrequently from the remnant sites (Table 1). Some of these species have relatively broad resource requirements and as such are likely to inhabit the cleared lowland area providing their habitat requirements are met. For example, *Pogona barbata* can be common in agricultural areas and is often seen basking on fence posts (Michael, 2004). It appears to be at the eastern limit of its distribution in the Gilmore Valley region (Daly, 2004). *Delma inornata* was encountered beneath an embedded tree stump in a clearing adjacent to remnant vegetation. This species often utilises exotic perennial grass and is expected to occur in the tree plantings in the future (Cunningham *et al.*, 2007). Likewise, *Pseudonaja textilis* is widespread and common although can be difficult to detect during active searches. In other areas artificial substrates prove to be a valuable method for detecting this species along transect lines (Cunningham *et al.*, 2007; Michael *et al.*, unpublished data). In contrast, *Diplodactylus vittatus* has a more specialised habitat preference and is closely associated with rocky areas and as such, is unlikely to be encountered in the tree plantings. It is however, occasionally detected beneath fallen debris in lowland grassy woodlands in the region (Michael, 2004). *Ctenotus taeniolatus* was recorded on the same outcrop and often co-occurs with *D. vittatus* in the SWS, although it also appears to also inhabit sandy soils along major river systems in the bioregion (D. Michael, pers. obs). *Christinus marmoratus* was recorded on a number occasions beneath the exfoliating bark of large mature trees and can be one of the most abundant reptiles in fragmented landscapes (Cunningham *et al.*, 2007).

Two frog species were detected in remnants. *Uperoleia laevis* was recorded beneath corrugated iron approximately 1 km from the nearest water body. A single *Litoria latopalmata* was observed beneath a rock adjacent to remnant vegetation and approxi-

mately 500 m from a dam in the neighbouring property. Both species have rarely been recorded in the SWS (Caughley & Gall 1985; Lemckert *et al.*, 1995; Daly, 2004). The first documented record of *L. latopalmata* in the SWS was from a farm dam in the Carabost State Forest (Lemckert *et al.*, 1995). This was reported as a 130 km range extension from records in the ACT (Rauhala, 1994). Lemckert *et al.* (1995) also report that *L. latopalmata* had been heard calling from farm dams near the Wagga Wagga turn-off on the Hume Highway. In recent times it has been recorded from Mudjarn, Minjery and Ellerslie Nature Reserves (Daly, 2004) and Gundagai (M. Crane, pers. obs). This additional record, although not observed directly adjacent to a water body, is congruent with other observations in the SWS from farm dams, but also provides support to the notion that it is capable of range expansion (Rauhala, 1994; Lemckert *et al.*, 1995).

Our preliminary surveys have revealed a diverse range of herpetofauna inhabiting the VISY pulp and paper mill property. Based on cumulative species richness over the two surveys and trends from other long-term studies (Caughley & Gall, 1985; Sass, 2003; Michael, 2004; Cunningham *et al.*, 2007), the total number of species is predicted to increase over time, especially as additional species encounter and become established beneath the artificial substrates (an extensive ten year reptile data set comparing artificial substrates and active search methods in southern NSW is being analysed which will yield important information on the long-term use of artificial substrates; Michael *et al.*, in prep). The addition of ungrazed tree plantings on the property has been valuable in providing suitable habitat for several species, especially amphibians and species associated with grassy areas such as *C. tetradactyla*.

## ACKNOWLEDGMENTS

We would like to thank the staff from VISY for providing us with on ground support and for helping to establish the survey sites. We also thank Glenn Shea and the two reviewers for their constructive comments on an earlier draft.

**Figure 2. The Broad-palmed Frog *Litoria latopalmata* recorded sequestered beneath a surface rock during the September 2007 survey on the VISY pulp and paper mill property, Gilmore, NSW.**



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# HERPETOLOGICAL NOTES

## OBSERVATIONS OF ABOVE GROUND CALLING BY THE GIANT BURROWING FROG (*HELEIOPORUS AUSTRALIACUS*)

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Various texts and papers commenting on the calling activity of the Giant Burrowing Frog note that this species calls from either in burrows (Anstis, 2002; Penman *et al.*, 2004) or sometimes under the cover of debris or vegetation (Daly, 1996). This presumably is to shelter the male frogs from predators, which can be a serious threat around breeding sites (see Penman & Lemckert, 2007).

However, I have noted two instances of male Giant Burrowing Frogs calling whilst sitting on the ground completely exposed. The first was on 26 February 2002 at a pond in Olney State Forest, near Kulnura, NSW. I was surveying the frogs present after recent heavy rainfall and heard a calling Giant Burrowing Frog immediately my vehicle stopped and I opened the door. I approached the calling site on foot and the frog stopped calling every time I moved, making it evident it could see me. I shone my headlamp in the direction of the call and spotted a large male sitting on the sandy substrate approximately five metres from the edge of the water. The male was completely exposed and a metre from any form of cover.

The second instance was on 10 March 2007 near a permanent pond about 5 km further west of the first site and on the edge of Olney State Forest. I heard a male Giant Burrowing Frog calling across the road from the pond and went to locate it. As in the first case, it became evident the frog could see me as it stopped calling as I approached. A search with a headlamp revealed the male immediately through eye-shine. It was sitting on the ground at the edge of a culvert that ran under

the road. It was also calling on the sandy substrate in a completely exposed position, around 30 cm from the culvert. Heavy rains had fallen in the previous 24 hours.

A point of note is that I have made only three observations of calling in this region since 2001 and two of these have been of frogs calling whilst sitting exposed on the ground. This raises the question as to how regularly surface calling occurs?

### ACKNOWLEDGMENTS

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# OBSERVATIONS OF POSSIBLE ANTIPREDATOR DEFENCE MECHANISM OF *CYCLORANA NOVAEHOLLANDIAE* (ANURA: HYLIDAE) AT TAROOM, CENTRAL QUEENSLAND

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We present an observation of a behavioural display of the New Holland Frog, *Cyclorana novaehollandiae*. The frog was observed at 9:00 PM on 12 March, 2008, near Taroom in central Queensland. The Taroom region (25°28'30"S 150°07'22"E, WGS84 datum) had experienced average rainfall in the preceding wet season; however, this followed several years of below average annual rainfall. Approximately 52 centimetres of rain fell in the two weeks preceding the observation, which triggered a breeding event for the region's amphibian fauna.

The frog was initially observed on a sandy track adjacent to fields of improved pasture that are used for cattle grazing. Grass cover was dense adjacent to the track and grass height was to approximately 20 centimetres. Ponded water was common throughout the region within depressions and road verges and creeks were generally flowing well. Most creeks in the locality are ephemeral in nature and flow only during the peak of the wet season.

An adult *C. novaehollandiae* (snout-vent length of approximately 10.5 centimetres) was observed to perform a display when confronted by several observers with spotlights. The frog adopted a pose similar to that observed on other *Cycloranas*, whereby the head and body is raised off the ground (Williams *et al.*, 2000). In addition, it also gradually inflated its body which made the frog look much larger and taller. The frog began to vocalise producing a series of short croaks and groans which gradually became louder and more drawn out. The vocalisations continued for several seconds before terminating with a loud explosive croak with the mouth opening to a large gape. The vocalisations were followed by vertical leaping, which propelled the frog several centimetres off the ground. Despite being cap-

tured and restrained by the legs, the frog repeated the leaping behaviour several times.

We suggest that the observed behaviour of this frog supports a hypothesis made by Williams *et al.* (2000: 442) that "the emitting of defensive calls followed by jumping in Australian frogs would startle and repel some predators".

Amphibians possess a range of defence mechanisms intended to deter predation by larger animals. Antipredator mechanisms include the production of foul-tasting, noxious, sticky or toxic skin secretions. These biochemical defences often occur in conjunction with morphological and behavioural modifications that are intended to distract or discourage potential predators. Williams *et al.* (2000) observed that some *Cyclorana* species (including *C. novaehollandiae*) secrete a thin, clear lubricious secretion, but which is not odorous. Skin secretions were not evident on this particular *C. novaehollandiae* individual.

Like many hylid frogs, *Cyclorana* produce vocalisations when threatened; however we are unaware of vertical leaping behaviour being previously reported for *C. novaehollandiae*. Tyler (1976) noted that *C. cultripes* emits a defensive vocalisation that is accompanied by vertical leaping. We are unable to ascertain the cause of the behaviour of this frog, whether it be a defensive response or a fear response to a perceived threat. However, our observation may show that this behaviour is more widespread within the genus.

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Stuttering Frog *Mixophyes balbus* from Olney State Forest, NSW. See article on this species on p. 84. (Photo: A. White)



Ornate Nursery Frog *Cophixalus ornatus* from Upper Daradgee, Queensland. See article on this species on p. 96 (Photo: G. Turner).